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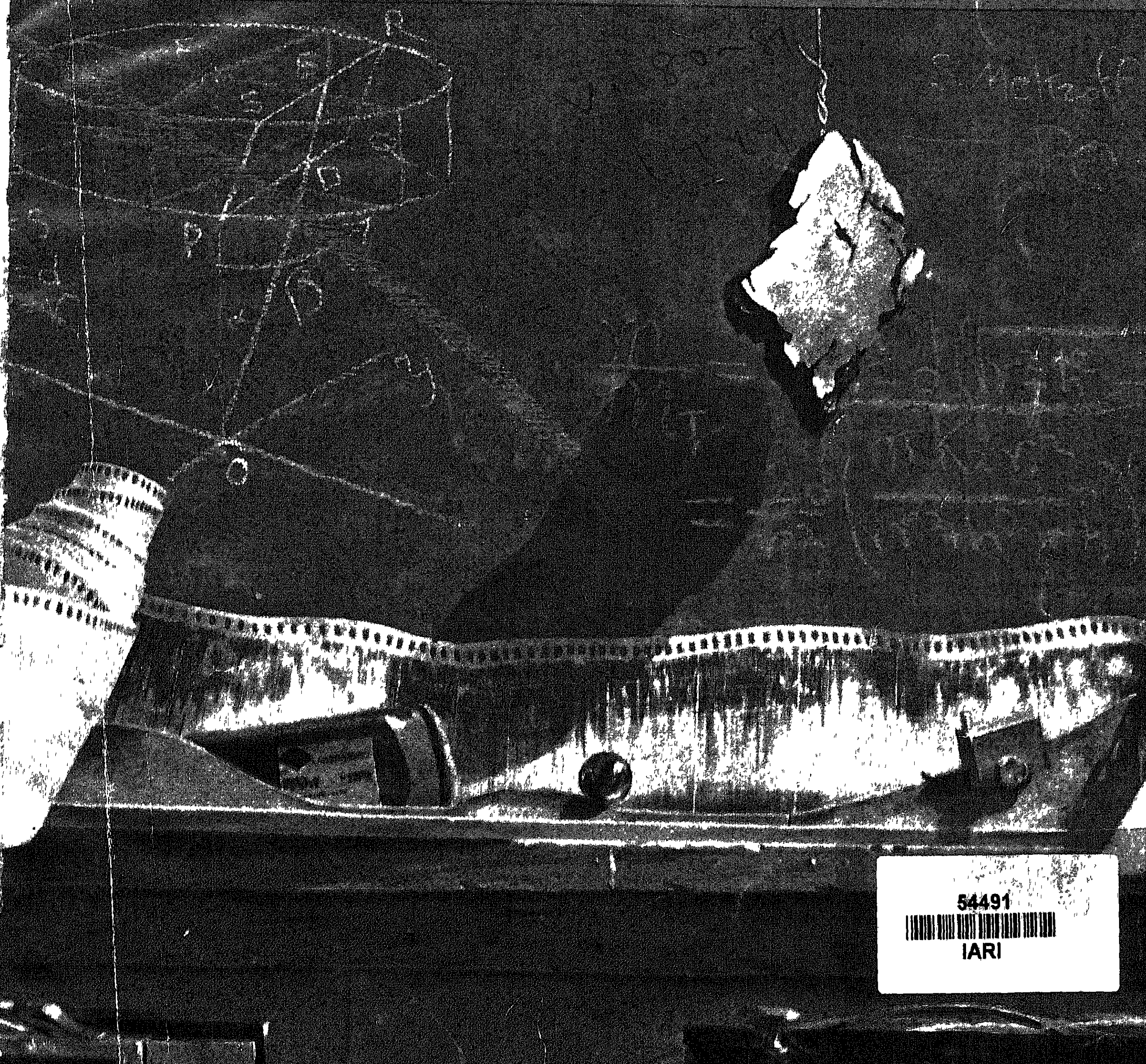

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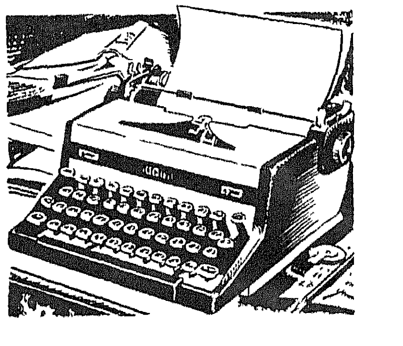

Sirs:

Two passages from your interesting November issue are illustrative of something or other.

"No biological principle is clearer than that every living thing—from man with his rapaciously expanding control over the environment, to the patient, insensible slime mold—lives in harmonious adjustment *to the conditions of its life*." From "Gulliver Was a Bad Biologist," by Florence Moog, page 55.

"The human brain may be as far along on its road to destructive specialization as the great nose horns of the last of the titanotheres." From "Cybernetics," by Norbert Wiener, page 18.

G. E. GATES

Biology Department
Colby College
Waterville, Me.

Sirs:

Some remarks in a letter by Mary van Kleeck, published in the November issue

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LETTERS

of *Scientific American*, cannot pass without question or challenge. One of the curious aspects of some thinking is a stubborn unwillingness to face facts when the facts run against the grain of emotional life

T H Malthus was one of the most important and influential writers who ever lived. A century ago, the mere reading of his book illuminated the thinking of both Darwin and Wallace, and today those who face the facts of poverty and hunger among three fourths of the people of the world know that Malthus was precisely right in pointing out that population tends to increase in geometrical ratio, while the productivity of the soil and even of the sea cannot possibly exhibit any such tendency.

There are three main reasons why the United States could afford to send food abroad in the past few years.

1. There are 15 million fewer horses and mules on farms than there were a generation ago. The land that once had to produce corn, oats, and hay for these animals—and the other millions which still swarmed in city streets—would produce enough food for human consumption to take care of our own population increase in that time.

2 The weather has been highly favorable for the past several years In the bad years of 1931-1935 our average corn production was 22.7 bushels to the acre. In the good years of 1941-1945 this jumped to 32.7 bushels, a gain of 44.7 per cent

3. We have hybrid corn. This may add about one-sixth to our annual productivity of this all-important crop.

It is fervently to be hoped that *Homo sapiens* will have gumption enough to cut his reproduction rate to fit his food supply. There is mighty little evidence that more than a trifling minority of the earth's billions have that much sense. Even after the horrible slaughters of war there are more people in Europe than there were 10 years ago. The facts seem to indicate that Malthus was right. Hence the post-war revival of interest in his thesis and of alarm that his predictions are visibly coming true.

Your correspondent must also be reminded that science has prolonged the expectancy of life. It is highly probable that what medical science has done to curb pestilence and save children from early death has more than balanced the gains in food production due to all the other sciences.

ELBERT H. CLARK

Hiram College
Hiram, Ohio

50 AND 100 YEARS AGO

JANUARY 1899. "Dr. Becquerel has announced to the Academy of Sciences at Paris the discovery of a new supposedly elementary substance which has a close affinity to barium. The correspondent who cables the news states that its discoverers M. P. Curie, Mme. P. Curie and M. G. Bemont have named it 'radium.' "

"As a result of the investigations of Prof. Buchner, of Tübingen, another of the fetiches of old chemistry is destroyed, namely, that living cells are necessary to fermentation Prof. Buchner grinds yeast with quartz sand in order to disrupt the cells, and submits the moist mass to a pressure of 500 atmospheres. The liquid content of the cells is removed and the cells totally disrupted. The filtered liquid is of a clear, or slightly opalescent, yellowish color, retains the odor of yeast, contains considerable carbon dioxide and some albumen. Most interesting is the behavior of yeast juice toward sugars, fermentation being set up much more quickly than by yeast, and proceeding much faster The gas evolved is almost pure carbon dioxide. When carefully dried at low temperature, the fermenting principle is not destroyed, and it is possible that, when desiccated, the activity of the ferments may be preserved indefinitely."

"The expedition which was sent out by the Swedish government in search of Andrée, the Arctic explorer who attempted to reach the North Pole in a balloon, has returned from Northern Siberia, where months were spent in fruitless efforts to learn the fate of Andrée and his two fellow voyagers."

"As is well known, Napoleon Bonaparte died of carcinoma of the stomach, at the age of fifty-two, his father having previously died, at thirty-eight, of the same disease. When Napoleon was born his mother was very young, between sixteen and twenty In commenting on these facts, Mr. Hutchinson states that cancer is more common in the children of aged parents than of young ones, and suggests that the outbreak of cancer in Napoleon was probably due to inheritance."

"A highly interesting theory has been proposed by Prof. B. Grassi, on the connection between mosquitoes and malaria. The theory that these insects disseminate the germs of malaria by their punctures seems to have been first brought into notice by Laveran; but Dr Grassi for a long time had doubts on the subject, owing to the absence of malaria from certain districts where mosquitoes abound. A careful classification of the various species of gnat found in different districts has now led him to the conclusion that, while certain kinds are not confined to malarious regions, the distribution of others coincides very closely with the distribution of the disease. The common Culex pipiens is to be regarded as perfectly innocuous. On the other hand, a large species (Anopheles claviger, Fabr.) is constantly found associated with malaria. These facts open up new hopes that it may be possible to stamp out malaria by taking proper steps for the destruction of mosquito larvae in districts where dangerous species abound."

"Prof. Roentgen, the discoverer of the X-rays, has been called to the Chair of Physics at the University of Leipzig from the University of Wurzburg."

JANUARY 1849. "The California gold excitement is as strong in our city as ever. In one day last week ten vessels sailed from this port. Throughout all the States, the accounts that reach us contain evidences of the gold fever raging in almost every hamlet. It is calculated that no less than 150,000 emigrants will be on their way to California from the States in two months."

"Morse's Telegraph line to Philadelphia is now in operation, from the office in Hanover street, New York, direct to Philadelphia."

"The British Government are going to lay telegraph wires across the Irish Channel, from Wales. This is certainly a great undertaking for the wires have to be laid in pipes in the bed of the sea, a distance of 60 miles."

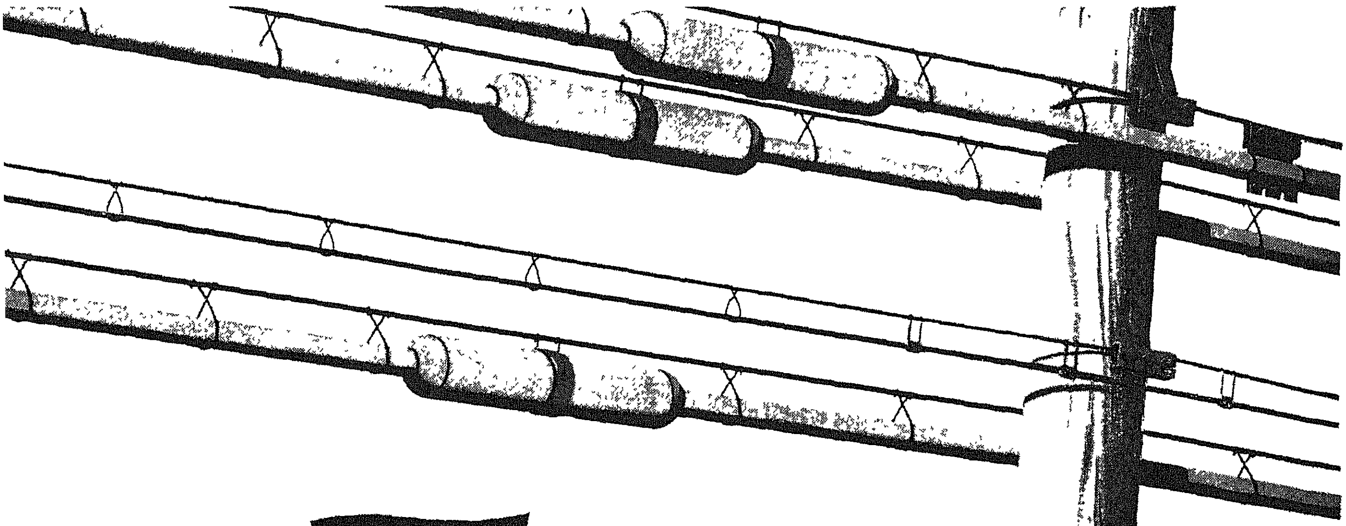
"Light travels with the amazing velocity of 192,000 miles in a second of time. It may be interesting to know how philosophers have been able to determine, with such certainty, that light really travels with the amazing velocity; for the fact is known as certainly as any phenomenon in nature. The method adopted was the following:—The eclipses of the satellites or moons of the planet Jupiter had been carefully observed for some time, and a rule was obtained, which foretold the instants, in all future time, when the satellites would glide into the shadow of the planet, and disappear, or again to emerge into view. Now it was found that these appearances took place sixteen minutes and a half sooner when Jupiter was near the earth, or on the same side of the sun with the earth, than when it was on the other side; that is to say, more distant from the earth by one diameter of the earth's orbit, or path in the heavens which it takes in revolving round the sun, and at all intermediate stations, the difference diminished from the sixteen minutes and a half, in exact proportion to the less distance from the earth. This proves, then, that light takes sixteen minutes and a half to travel across the earth's orbit, and eight minutes and a quarter (or half that distance, or to come to us from the sun."

"M. Adolphe Brongniart considers everything to prove, on the one hand, that the different vegetable creations which have succeeded each other on the globe, have become more and more perfect; on the other hand that the climate of the surface of the earth is greatly modified since the earlier times of the creation of living beings up to the commencement of the present epoch."

"Capt. John Taggart, of Charlestown, is building a machine to navigate the air We have seen a picture of the balloon, and a miniature of the sails and the way he creates a new element with them. President Everett and Treadwell, of Harvard College, and Mr. Pook, the naval constructor, we understand have expressed favorable opinions of the project. Mr. Taggart had better take the advice of Paul, 'abide by the ship.' "

"One of the subjects recently discussed in Congress, is that of a proposition that the swamps of the Everglades, shall be ceded to the State of Florida, on condition that the State shall drain them, and in draining them, make a canal in which vessels may save the passage round the Peninsula of Florida and the dangers connected with it."

"On Christmas morning last, Mr. Charles Ellett, Jr. the contractor of the Suspension Bridge at Niagara Falls, together with Mr. George Hamlin, drove across the bridge in a canter, and returned at a trot. It would truly appear to be a perilous feat, thus to drive across the apparently frail structure of iron wire suspended 230 feet above the boiling stream."



The case of the Creeping Sleeve

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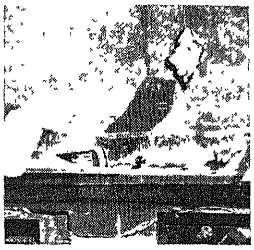


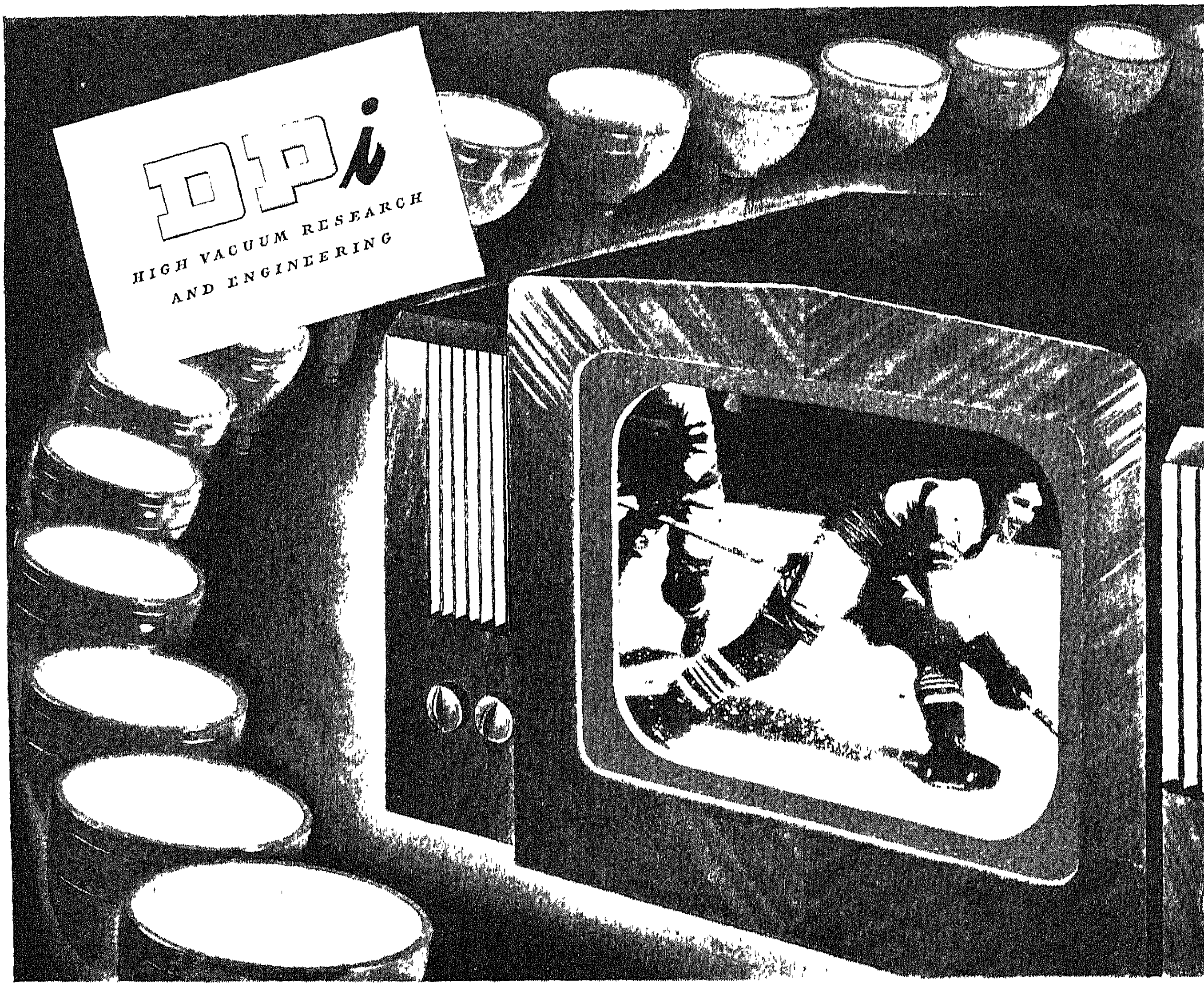
THE COVER

The painting on the cover shows laboratory equipment used in studies of the upper atmosphere (*see page 30*). The strip of photographic paper on the bench is a record of radio echoes obtained from the atmosphere with radio set at the lower left corner of picture The echoes measure the height of ionospheric layers, meteors, auroras and other detectable electrical phenomena. The ball rolling on the curved track is a device used to picture in mechanical terms the behavior of the radio waves The small hills in the track represent layers of resistance encountered by the waves as they pass through the atmosphere The drawing on the blackboard shows the section of the atmosphere being studied, the green chalk line is a meteor track The object hanging at the right is a meteorite. The equipment shown is in the laboratory of John A Pierce at Harvard University.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Credits
12-15	Adolph Brotman
16	General Aniline and Film Corporation
19-20	Henry Billings
21	General Aniline and Film Corporation (*top*), James W. Welgos (*bottom*)
23-27	David Stone Martin
30	Official U. S Navy-Johns Hopkins Photograph
32	Carl Stormer
34-35	Eric Mose
36	American Museum of Natural History (*top*), C. W Gartlein (*bottom*)
37	Official U S Navy Photograph (R Tousey and F. S. Johnson)
39	Norman Lockyer Observatory
40-41	Carl B Boyer
42-45	New York Public Library
46-47	Bradford Washburn
48	Eric Mose
49-51	Bradford Washburn
53	Arthur Seymour
54	American Museum of Natural History
56-58	Princeton University Press
60	Robert Cox
62	J. M. Holeman
63	Russell W. Porter



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CONTENTS FOR JANUARY 1949 — VOLUME 180, NUMBER 1

ARTICLES

DEPARTMENTS


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SCIENTIFIC AMERICAN

JANUARY 1949 VOL. 180, NO. 1

CANCER AND ENVIRONMENT

Scientific and technological progress have exposed man to new physical and chemical agents. Some are believed associated with the rise of cancer as a cause of death

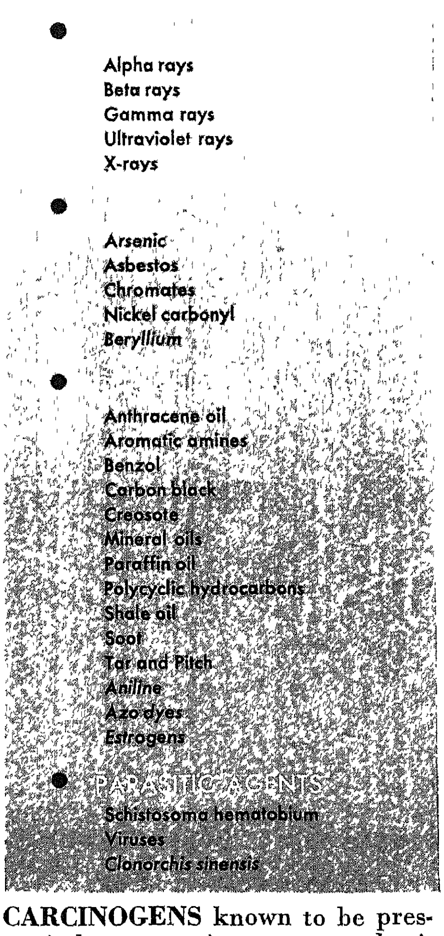
by Groff Conklin

THE industrial era in its full expansion is barely two generations old, yet during that short period literally thousands of entirely new chemical and physical constituents have been added to the human environment. Few of these constituents have been exhaustively analyzed for their long-range toxic effects on man. They are now being studied, however, as possible contributors to the rise of cancer.

The growth in the relative importance of cancer as a cause of death is one of the outstanding medical facts of the past 50 years. The disease has moved from eighth to second place in the U. S. since 1900, and today only heart ailments surpass it. The reasons customarily given for this rise—improved diagnosis and the aging of the population—do not entirely explain it. They provide no satisfactory answer to the fact that approximately seven and a half per cent of the known cancer deaths in 1944 occurred in age groups under 40. There is evidence, moreover, that the disease is not an inevitable consequence of bodily degeneration due to age, although the changes of senescence under certain conditions may be contributing factors. It seems certain that there is a net increase in true cancer deaths, if only because fewer people die from other diseases than in the past.

An explanation of this increase and of the causes of the disease is therefore being sought in our environment, so much more complex than it was in 1900. The investigation is focused on carcinogenic agents, as the substances that produce cancer are called, and on the general question of the extent to which the increase in cancer may be caused by agents in the environment that have hitherto been considered comparatively harmless.

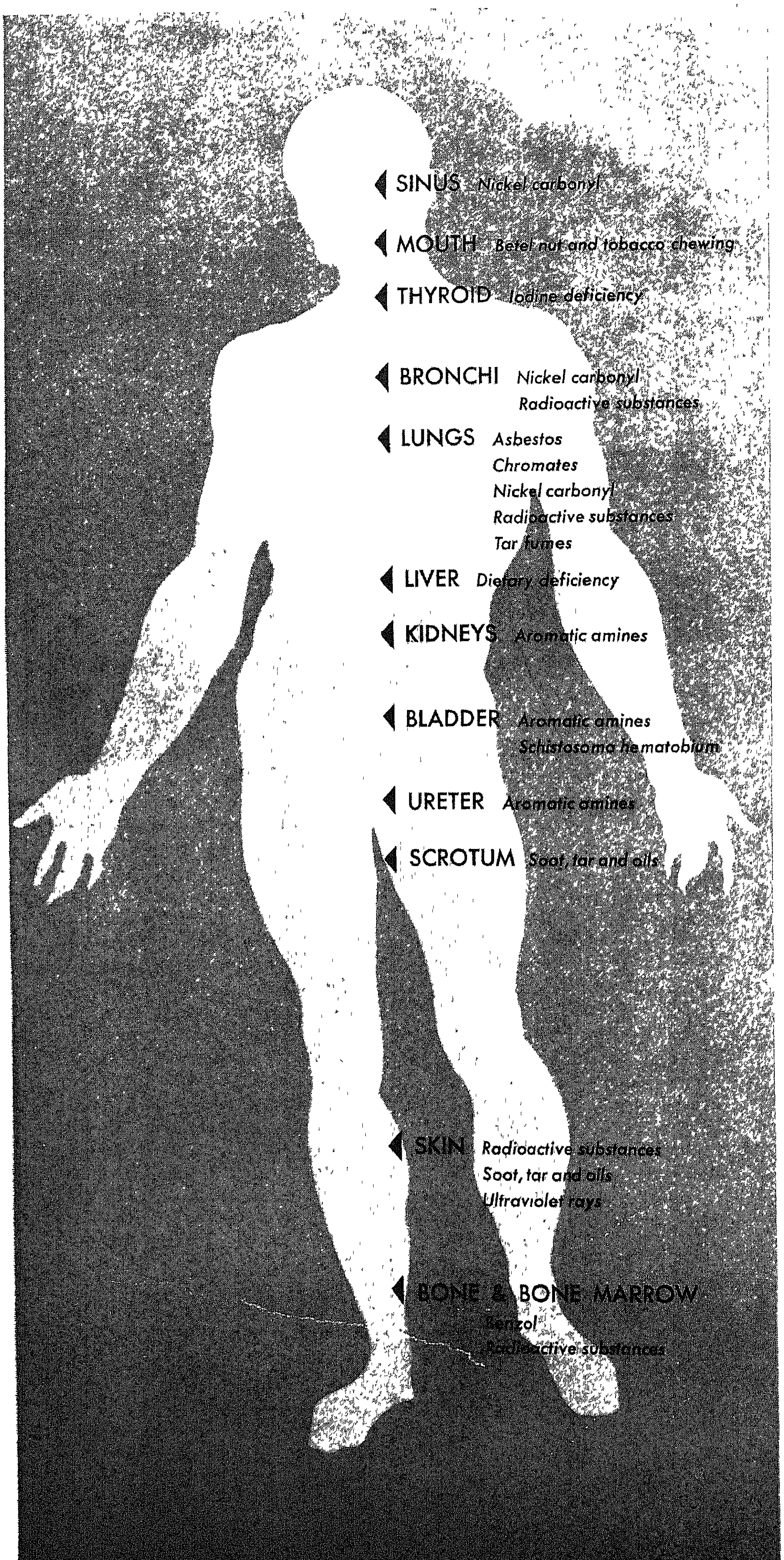
It has been established that certain agents to which people are exposed in industrial occupations cause cancer if the exposure to them is sufficiently intense and prolonged. As an example, over 75 per cent of the miners in the Schneeberg cobalt-uranium mines of Germany die of lung cancer, more than 50 per cent of those in the Joachimsthal uranium mines across the border in Czechoslovakia die of the same cause. In the 18th century it was learned that among chimney sweeps exposed to intense concentrations of soot, deaths from cancer were between three and four times as high as those in the general population. It is known also that certain common substances in concentrated doses can produce cancer; for example, mouth cancers are uncommonly frequent in a tribe in India which smokes cigars with the lighted end in the mouth. This causes them to suffer frequent burns and to receive a concentrated dosage of tobacco tars.



CARCINOGENS known to be present in human environment are classified. Less certain agents are in italics.

Although these are special cases of intense exposure, they naturally suggest speculation as to whether the average human being's relatively mild but long-continued exposure to new substances in a contaminated atmosphere, in processed foods, in cosmetics and in other elements of our environment may be a contributory cause of cancer. We have as yet no conclusive evidence for or against this possibility. We have no accurate estimate of how many of the artificial substances common to our industrial civilization may be carcinogenic under special circumstances, nor how many seemingly harmless substances, interacting with others that appear to be equally innocuous, may produce carcinogenic results.

There are, of course, many theories about cancer's causes: chronic internal irritations in the body, changes in cell



ORIGINAL SITES of malignant growths due to carcinogens in the environment are scattered among almost all the organs of the body. Some agents, such as the aromatic amine dye intermediates, regularly affect the same organs even though they may use any one of many routes for attack.

metabolism, tissue degeneration, viruses, and so on. Most of these theories, however, describe mechanisms rather than first causes. Indeed, with two or three exceptions all of them seem to require the presence of a triggering agent.

Possibly the most fruitful current theory is the one that attributes cancer to mutations in body cells. Cancer-causing mutations, it has been demonstrated by experiments, may be produced by ultraviolet radiation, X-rays, radioactive substances, and a number of chemicals. While more than 99 per cent of all cancers are still of unknown origin, nearly all of those for which a proved cause has been found arise as the result of external agents. These seem to mutate the cells into a state which is, or can become, cancerous.

The methods by which these external agents act upon the body vary considerably, depending on the substance involved. Some carcinogens may cause cancer directly. Examples of these are tar, the mineral oils and certain dye intermediates known as aromatic amines. Tars generally affect the skin. Mineral oils may cause cancer of the lungs through inhalation. The aromatic amines, strangely, concentrate on the bladder, no matter what their route of attack. Whether they enter the body through the respiratory system, the mouth or the skin, they gravitate to the genito-urinary system and there build up a concentration that eventually causes cancer.

Other agents seem to cause cancer by altering organs so that the organ itself produces a carcinogen, resulting in a cancer. The mechanism of this transformation is little understood. It is known that some radiations and certain metallic compounds including the chromates, the arsenicals, nickel carbonyl and possibly asbestos, cause cancer in this relatively roundabout way.

RADIOACTIVE materials are less specialized in their effects; they can produce a wide variety of cancers. They may cause skin cancer by direct attack on the skin, and lung cancer in people who inhale radioactive dust. When exposure is intensive and prolonged, as in the case of the women who worked in the radium watch and clock dial industry some 25 years ago, they produce bone cancer. And a slight but very prolonged exposure to penetrating radiation can result in leukemia, a cancer of the blood cells. The latter kind of cancer is often found among radiologists whose whole professional lives have been spent in theoretically safe and well-protected dealings with X-rays or radioactive materials.

Most subtle of all carcinogens are those believed to cause general metabolic disturbances that produce cancers in a roundabout way. Thus the liver may produce carcinogens that can cause it or some other tissue to turn malignant. Among the agents thought to have this effect are the

azo dyes and certain chlorinated aliphatic hydrocarbons But the mechanism involved is so obscure that the carcinogenicity of these substances has not been completely proved

One aspect of such indirect causation, however, is susceptible of proof. Among some Negro tribes working in the gold mines of Africa, an excessive incidence of cancer of the bladder has been traced to deficiencies in the workers' diet It was found that most of the Negroes had lived for years on a vitamin-deficient diet of pap and sour milk Only recently South African research workers have succeeded in producing cancer of the liver in rats fed just this diet.

IN view of the relative novelty of the concept of environmental cancer, and of the small amount of well-organized research in this field, it is not surprising that most of the known carcinogenic agents have been found in industry. Here workers suffer exposures many times more concentrated than the average citizen encounters in a non-industrial environment Fully 90 per cent of the known carcinogenic agents are industrial, and a similar proportion of cancers of known cause arises from carcinogens of industrial importance. These known agents are listed in the chart on page 11.

The difficulties in the large-scale study of carcinogenic agents are formidable The modern environment is so ramified that efforts to evaluate it in terms of long-range carcinogenicity may appear nearly hopeless. Nevertheless, the techniques already developed in the study of occupational carcinogens may be of some value in analyzing the environment as a whole, even though more refined methods may have to be developed if such a program is to be successful.

The two principal methods now used to uncover the more obvious occupational cancer hazards are animal experimentation and statistical analysis. Cancers have been produced in experimental animals by most of the known physical and chemical carcinogens. Hundreds of other substances have been and are being tested Some that have been shown to be carcinogenic in animals have not as yet been proved dangerous to man, or else they do not form a part of his normal environment Among these substances are urethan, ergot, selenium, and diethylene glycol.

One aspect of the work on animals that is important in considering human cancer is the phenomenon known as "species specificity." Many carcinogens that cause cancer in some animal species have thus far proved harmless to others. For example, certain tars, when correctly applied, produce skin cancer in mice, rats, rabbits and dogs, but not in monkeys. Rats and mice get skin cancer from ultraviolet rays, but rabbits do not. The probability is that specialized metabolism is at the bottom of this species specificity for cancer. If such metabolic differences were completely understood, human beings might be endowed with resistance to certain types of cancer by modifying the individual's metabolic processes. Such ideas are still beyond the realm of practical application in man. In experimental animals, however, cancer susceptibility or resistance to certain external carcinogens, such as several of the azo dyes, may be created at will by the omission or addition of certain vitamins in the diet

Without animal experimentation, scientific proof of the carcinogenicity of various substances and radiations would be nearly impossible. On the other hand, laboratory experiments alone cannot prove definitely that such agents are dangerous to man Other methods must be used, and the principal instruments so far available have been statistical studies and medical records.

In large, unselected population groups, variations in the incidence of one kind of cancer are usually not sufficiently marked to be significant. That is why environmental carcinogens are usually difficult to detect. Up to half a century ago, indeed, evidence of specific extrinsic causations of cancer was discovered largely by clinical observation. Physicians practicing in urban or manufacturing areas began to notice a remarkably high incidence of certain types of cancer among workers in individual trades. Such was the case in the diagnosis of cancer of the scrotum in chimney sweeps. Discoveries by direct observation continue to be made, as in the case of radium and X-ray cancers that occurred with alarming frequency among people working with these agents in the not so distant past.

BUT observation has its limitations. Unless very careful medical records are kept, or unless workers remain in a carcinogenic job for many years, the fact that the job is carcinogenic may escape notice. Characteristic of environmental cancers is the long period between the beginning of exposure to the carcinogen and the actual appearance of a tumor. A worker who leaves a dangerous job before the cancer appears may later develop a malignant tumor without realizing its origin.

The process of tracing cancers to their source through medical records and health statistics has become a work of skilled deduction. When a given community is found, on careful examination of its illness and mortality statistics, to have an unusual number of cases of cancer in certain sites, the biometrician at once suspects the presence of an active environmental carcinogen. The chances today are very great that it will be traced to one or more factories in the area, since so few non-industrial carcinogens have been found. Conversely, if it is known that certain plants are producing or using known carcinogens, the statistician searches for evidence of an abnormal incidence of cancer among men who are employed in these plants.

Obviously such investigations present difficult problems and demand a high order of judgment. It has often been said that statistics can be used to prove both sides of a question. Environmental carcinogenesis is no exception.

An example in American experience is a study which was made some time ago of the incidence of lung cancer among 40,000 workers in an industry suspected of producing a carcinogenic agent. It was known from studies in other countries that lung cancers were exceptionally frequent in this industry, and there was no evidence that the American manufacturing methods differed in any major respect from those abroad. Yet this study reported no lung cancers at all! In any group of 40,000 adult males several cases of lung cancer are bound to occur, merely on the basis of the incidence of the malignancy in the population as a whole. The results of the study surely suggest a lack of thoroughness in the collection and evaluation of data

A CLEAR example of the intelligent use of statistics as a tool in uncovering environmental carcinogens is the way in which cancers of the bladder were identified as an occupational hazard in plants using the aromatic amine dye intermediates mentioned earlier. The following composite description, based on a number of European and American investigations of this problem, illustrates the method:

The people in a certain industrial region have a frequency of bladder cancer that is a slight fraction higher than normal. The variation is well within the range of random probability, but the fact that several cases of this not too common malignancy have been found in a single community leads to a further study of the region. It is found that the incidence of bladder cancer jumps from .02 per cent in the province as a whole to .1 per cent in the particular community under study, an increase of 400 per cent. On further investigation it is learned that among the workers in a particular dye plant in the town, 5 per cent are suffering from or have died from bladder cancer—nearly a 5,000 per cent increase. Following this clue, every operation in the plant is studied, and one particular job is found in which over 90 per cent of the workers have bladder cancer or have died from it Obviously the focal point of the disease has been established.

It is from just such relatively slight statistical anomalies that much of the original evidence of carcinogenesis in industry arises. Of course, as more carcinogens become known and are added to the list, the statistical techniques change. With the cooperation of the industries involved, medical and public health experts go directly into the plants and study the operations and the workers. Often, however, public medical and death records offer the

only reliable source of information Many industries actually do not know of the existence of carcinogenic hazards in their factories The study is so new that only plants in which the incidence of specific cancers is notoriously high are aware of the problem. A few industries do know of the existence of carcinogens in their plants. and probably some of them have developed their own methods of coping with them.

The reluctance of industrial managements to publicize the existence of a carcinogenic hazard is understandable, for it could easily become difficult for plants so labeled to recruit workers, or even to sell their commodities. To make factories employing carcinogenic materials safe to work in, furthermore, sometimes requires extensive and costly alterations. If one firm makes such alterations and others do not, the competitive position of its product is endangered.

Generally speaking, however, employers are no more responsible for the lack of information about industrial cancer than are the many thousands of physicians who have cancer patients in industrial areas or who actually are associated with factories. It is an unquestionable fact that an appreciable number of occupational cancers slip through the hands of doctors unidentified. This is due in a great degree to a general ignorance of the occupational aspects of cancer. Physicians have never been adequately informed of the basic symptomatic and sociological factors involved in identifying occupational carcinogenesis.

THE medical profession should be better educated about the need for exhaustive case histories which carry the individual's job record in detail back as far as 25 years, about the urgency of checking medical suspicions of industrial cancer hazards against careful epidemiological studies of all the workers in a plant, and about the paramount importance of impressing plant management with the seriousness of the problem.

The standard protective and hygienic measures currently used in industry to combat industrial poisons and other health hazards are not always adequate for the control of occupational cancer. The following case history is a compelling illustration: Some 30 years ago workers in one of the newer metal industries began to develop lung cancers. At that time the cancers were found to remain latent from 10 to 15 years. The incidence was unusually high in certain operations where the carcinogenic substance was present in particularly high concentration as an airborne dust. An effort was made to safeguard these operations. Up-to-date equipment for removing dust and fumes was installed, and a standard industrial hygiene program was inaugurated, including protective clothing. But the outcome was exactly the opposite of what had been expected The incidence of lung cancer did not diminish; in fact soon afterward cancers began to appear among workers who had been exposed for less than six years, a much shorter period than had been previously observed. What had happened was that at the time when the protective measures were adopted the factory had also begun to use a more finely ground material to improve production. The finer dust, though present in a much lower concentration than the original material, penetrated farther within the bronchi of the lungs. Thus despite the installation of the latest in protective devices and procedures, the cancer hazard was actually increased.

IT is obvious, therefore, that the control of occupational carcinogenesis—and even to a great extent of cancers stemming from more indefinite environmental agents, if and when they are discovered—is a public health problem of considerable magnitude This is made even more apparent by the scope of a control program that has been proposed by Dr. Wilhelm C. Hueper, head of the new Environmental Cancer Section of the National Cancer Institute. Dr. Hueper, one of the world's leading experts on occupational cancer, has studied the problem in the U S. and elsewhere for many years. Several of the elements of his program have already been put into effect in European countries. The program proposes that carcinogenic agents be eliminated from industrial, military and civilian use as far as is possible and practical; that manufacturing processes which must use such materials be enclosed; that the community be protected by the prevention of the discharge of carcinogenic wastes; that factories be licensed and inspected; that workers be provided with protective clothing, equipment and medical supervision, including frequent and thorough physical examinations.

The Environmental Cancer Section of the Institute, which is a part of the U. S. Public Health Service, is preparing an immediate, comprehensive campaign of education and information, the purpose of which is to bring physicians to a realization of the existence of the problem. Plans are also under way to make exhaustive surveys of major industrial areas in the nation. These studies are essential preliminaries to the institution of the controls that Dr. Hueper has suggested.

Many of the control recommendations admittedly are far-reaching in their implications. Years of work will be required to put them into practice with maximal effectiveness. This is particularly true of the recommendations for social controls. On the technical side, some of the elements can be instituted at once and without great expense, if management and labor can be persuaded to agree to them.

For example, effective medical and sanitary supervision of exposed workers can be undertaken immediately. This supervision should include X-ray examinations at frequent intervals; careful clinical study of suspicious lesions; preparation of exhaustive and detailed job analyses and case histories; regular quarterly or semiannual physical examinations of all workers who might possibly suffer exposure to

City	Percent of total possible sunlight	Skin cancers per 100,000 population
DALLAS ★	60—80 percent	140
NEW ORLEANS ★	62—64 percent	129
PITTSBURGH ★	50—57 percent	37
★ DETROIT	25—40 percent	24

CARCINOGEN IN NATURE is sunlight. Such natural carcinogens, however, are few. An abnormally high concentration of arsenic in drinking water has been shown to cause cancer of the skin and internal organs. Infections of certain parasites have also been found to lead to malignant growths.

the carcinogenic agents, a constant review of dangerous plant operations to enforce constant good housekeeping and to check on the level of carcinogenic dusts, fumes, and mists.

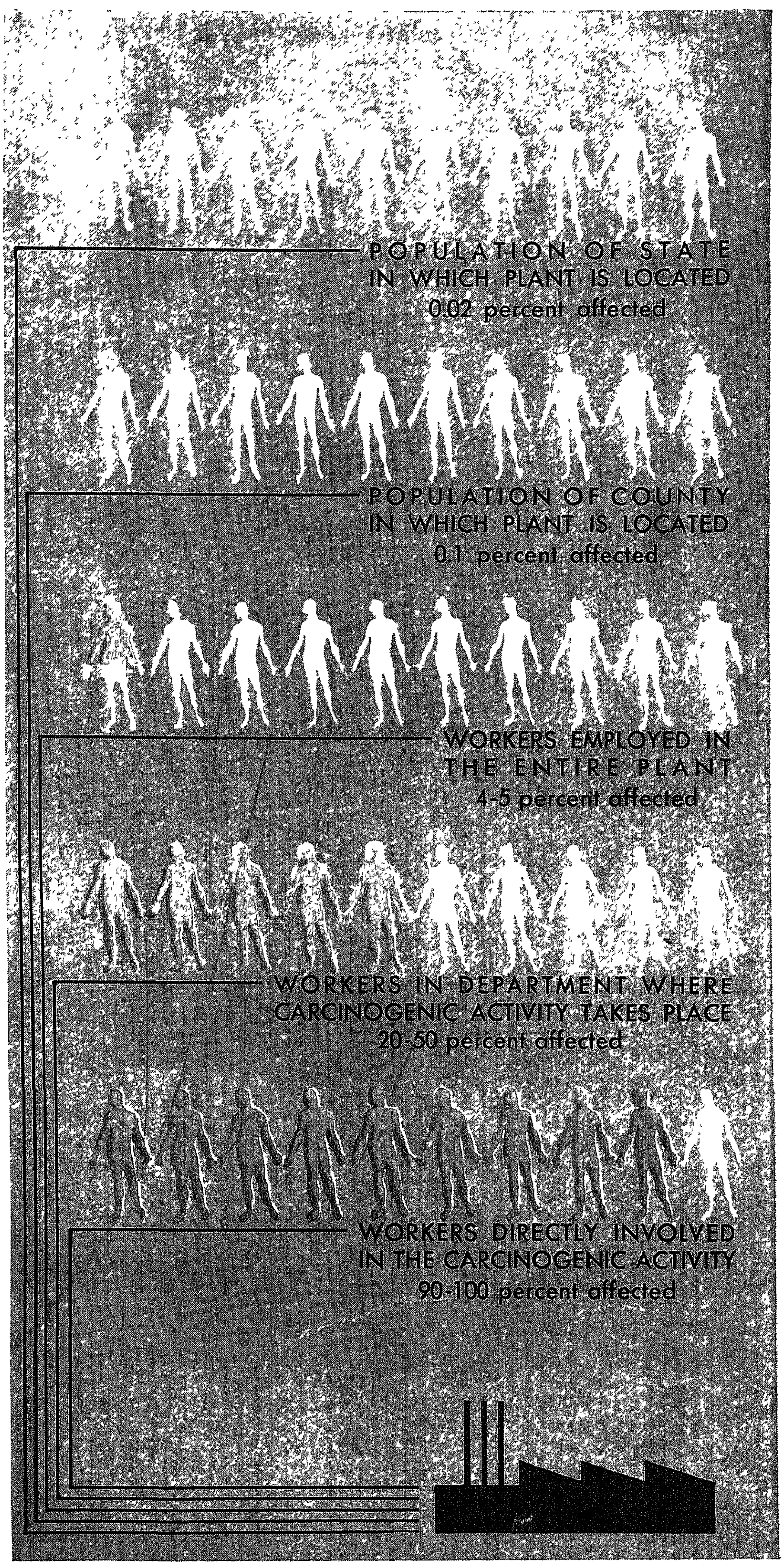
Protective measures for the workmen themselves are also simple and relatively inexpensive, although the enforcement of their use is sometimes made difficult by the discomfort they cause They include the regular wearing of respirators and sealed clothing whenever exposure to a carcinogenic hazard is likely, daily showers for all persons working in or near the hazardous operations, use of separate lockers for street and work clothes, and adoption of work techniques that will minimize the dangers of exposure.

Other, and more important, technical measures are likely to involve heavy expenditures for management. In some instances, entire factories would have to be rebuilt. Others would require costly waste-control equipment, such as electronic dust precipitators, and extensive remodeling to enclose carcinogenic operations and keep the workers from any contact with dangerous agents. Few plants could afford the necessary changes unless all other plants in the same industry were required to make the same improvements at the same time.

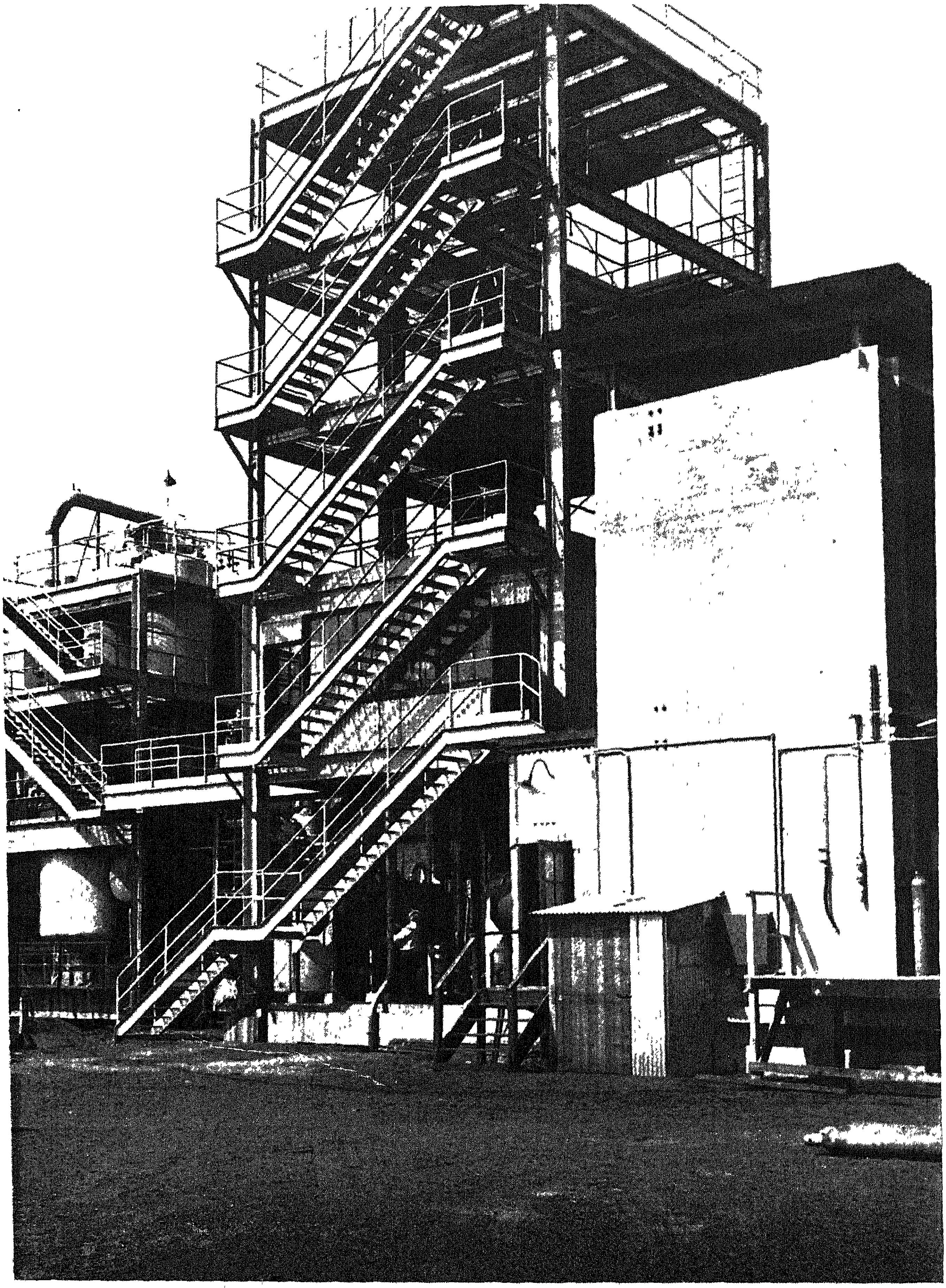
In some instances, such changes might possibly be undertaken as a result of an industry-wide agreement. In others, legislative and administrative enforcement might be essential. Such action would include factory licensing and inspection by government, improved compensation laws recognizing occupationally acquired cancers as compensable, and revision of the health codes to make occupational cancers notifiable just as are many other diseases. These measures would require coordinated and carefully planned action on the part of management, labor, the medical profession, state public health and labor departments, and state and Federal legislatures. A precedent for such a program has already been set by the successful control of communicable diseases through public health laws and through the organized cooperation in their enforcement of both private and public agencies.

How effective these controls would be in diminishing the hazards of still undiscovered environmental carcinogens is a question that only time can answer. Meanwhile, the known causes of occupational cancers would be placed under technical and social restraint, and patterns would be established for the future control of new carcinogens as they are found in our environment

Groff Conklin is a science writer and a former consultant with the National Cancer Institute.



EXTREME CASE of environmental cancer is represented by record of aromatic amine plant in Germany. Of workers directly in contact with chemical, 90 to 100 per cent developed cancer of the bladder. Running from top to bottom is illustration of statistical analysis used to locate such hazards.



PILOT PLANT to test new processes utilizing acetylene has been erected by the General Aniline and Film Corporation at Grasselli, N. J. The vessel in which the reactions are conducted is hidden behind the stout concrete wall at the right. The wall is a safeguard against the possible explosion of the highly reactive gas.

THE ARRIVAL OF ACETYLENE

The Germans developed remarkable new processes to utilize the reactive gas. These processes and some others may soon make it a powerful constituent of the U.S. chemical industry

by Herbert Yahraes

ACETYLENE is a colorless and practically odorless gas with a reputation among chemists for extreme touchiness. It is a close chemical relative of other simple hydrocarbons such as methane (marsh gas) and ethylene (a petroleum and coke by-product). But it is far more reactive; indeed acetylene, packing 54,900 calories of latent energy in each gram molecule, is one of the most energetic compounds known. Because concentrated acetylene forms explosive mixtures with air, it is dangerous to handle even at atmospheric pressure. Under higher pressure, it explodes on ignition with terrific violence. These qualities have not, until recently, been warmly regarded. Certain developments during World War II, however, have made the chemistry of acetylene a subject of wider interest among U. S. chemists and chemical engineers.

Acetylene was discovered by an English chemist named Edmund Davy in 1836. For 56 years it remained only a laboratory curiosity. Then on May 2, 1892, occurred one of modern chemistry's most fruitful accidents. In a small plant in Spray, N. C., a Canadian engineer named Thomas L. Willson and his partner, James T Morehead, a former major in the Confederate Army, were conducting experiments with an electric furnace They were seeking a process to obtain aluminum by the direct reduction of aluminum oxide to metallic aluminum. Willson decided that metallic calcium might make a reducing agent, and thought it might be obtained by reacting lime and carbon.

So Willson and his workmen mixed some whitewash lime with coal tar—in proportions that were happenstance but that proved providential—and shoved the mess into the furnace. After a run of several hours, the treatment yielded a grayish-white stuff, some of which was withdrawn and dropped into a bucket of water This produced an active reaction from which a gas bubbled. Willson hopefully concluded that his furnace product was indeed metallic calcium, which on contact with water would take up oxygen and release hydrogen. To find out whether the gas really was hydrogen, one of his assistants tied some oily waste to the end of a pole, lit it and swung the burning rag over the bucket The gas burned brilliantly—unlike hydrogen—and it gave off clouds of sooty smoke This was puzzling: if the substance in the bucket was calcium, what was the source of the carbon in the smoke?

Willson and Morehead sent samples of their furnace product to North Carolina State University. Laboratory analysis disclosed that the substance was calcium carbide, and that the gas given off when it reacted with water was acetylene. The two experimenters, though thwarted in their effort to produce aluminum, had happened on a method for manufacturing a product with great potentials of its own.

Calcium carbide was soon in commercial production, and acetylene gas became one of the signatures of the gaslight era. Its bright flame made it a fine fuel for bicycle and automobile lamps and marine beacons. The intense heat it produced was put to use in the oxyacetylene torch. Yet these uses did not begin to suggest the immense possibilities of acetylene as a chemical material. Indeed, the applications of acetylene, considering its potentialities, have been developed almost as slowly as were those of petroleum, which were restricted for several decades to the kerosene fraction.

Like the compounds in petroleum, acetylene offers a basic building block in organic chemistry. Its formula is C_2H_2, which is pictured by the organic chemist as $H{-}C{\equiv}C{-}H$, indicating that the acetylene molecule is composed of two carbon atoms joined by a triple bond, with a loosely held hydrogen atom at each end. This is a highly reactive arrangement The energy-packed molecule is unstable and therefore touchy to handle, but its instability also makes it a versatile building material, capable of forming a great variety of products

U S. chemists have been aware of these possibilities for at least 20 years, and an appreciable acetylene industry has developed in America. The great current interest in the chemical, however, derives from the wartime exploits of the German acetylene industry Without acetylene, Germany could not have waged World War II. Lacking petroleum or other plentiful sources for organic chemicals, Germany turned to acetylene as a basic chemical for producing synthetic rubber and other war materials As a result, German chemists developed some new processes which suggest that the possibilities of acetylene have barely been touched

NEXT month the chemistry of acetylene will enter upon a new phase. The General Aniline and Film Corporation will open a pilot plant at Grasselli, N. J., to explore and exploit some of the German processes and a few techniques of its own. An intensive study is to be made of the wide range of this versatile chemical, which already has yielded such diverse products as synthetic rubber and silk, eyeglass frames and false teeth, shower curtains and shoes. From these studies and those of other chemical firms very likely will come new plastics, textiles, solvents, lacquers, dyestuffs, drugs, and other materials not yet imagined.

The development of acetylene in the U. S. has been held back not only by the fact that the material is explosive, but also

because there has been no pressing need for it. The organic chemicals industry in the U. S. during the early part of this century was based principally on the fermentation of grain and sugar; after World War I, with the rapid advance of chemical technology, the industry shifted largely to petroleum. Thus even the Union Carbide and Carbon Corporation, the chief U. S. manufacturer of acetylene, entered upon the extensive development of a chemistry based on ethylene, an oil refinery product. Ethylene, the formula of which is C_2H_4, with only a double bond between the carbons, is less reactive than acetylene and therefore more limited in the compounds it can produce. It is, however, comparatively cheap, nonexplosive and sufficiently versatile to serve as the source of hundreds of chemicals.

Nevertheless, several important products were developed from acetylene during the '20s and '30s by U. S. and Canadian chemists. The first was acetaldehyde, the parent chemical for acetic acid, which is used in the manufacture of acetate rayon, movie film, and so on. Then came acetylene tetrachloride, from which was derived the solvent trichloroethylene, now one of the world's chief dry-cleaning fluids. In 1932 E. I. du Pont de Nemours & Company began to use acetylene to make the synthetic rubber neoprene. Meanwhile the Shawinigan Company of Canada had produced vinyl acetate, a basic material of the plastics industry, later developed by the Niacet Chemicals Corporation, which has since been absorbed by Union Carbide. Other companies developed vinyl chloride, another of the vinyl compounds. This material, also made from ethylene, is the plastic that has recently become familiar to consumers in the form of shower curtains and synthetic leather handbags. Because of their extraordinary toughness and resistance to physical and chemical abuse, these vinyl chloride leathers may soon provide major competition for natural leather in every end use from shoes to machine belting.

Some 200 million pounds of these vinyl compounds are now produced annually in the U. S. Known as vinyl resins, they are used, separately or in combination, to make molded articles, safety glass, electrical insulation, upholstery coverings, photographic film, washable wall fabrics, unbreakable phonograph records. During the war vinyl resins were used to make the liquid plastic that was sprayed on metal parts to protect them from corrosion during shipment.

The chemical processes for production of the vinyl compounds from acetylene are relatively simple. Vinyl chloride is made by reacting acetylene with hydrochloric acid; vinyl acetate, by combining acetylene and acetic acid, which itself can be made from acetylene. And all the U. S. and Canadian uses of acetylene were based on reactions that could be carried out at moderate temperatures and ordinary pressures then believed to be the only conditions under which acetylene could be safely employed.

Germany's wartime extremity, however, drove her chemists to experiments with acetylene in the danger zone of higher temperatures and pressures. Because she could not afford the luxury of building a chemical industry on her scarce supplies of grain or oil, Germany had begun to rely heavily on acetylene even before World War I. At the approach of World War II, I. G. Farben researchers began to work on the problem of applying heat and pressure to the gas to produce new materials. The work was directed by J. Walther Reppe, head of Farben's central research laboratory.

To control the explosive tendencies of acetylene, Reppe started to experiment further with certain techniques that had previously been worked out in the U. S. to keep acetylene from exploding in pressure cylinders used in connection with the oxy-acetylene torch. One of these methods was to lessen the reactivity of the gas by diluting it.

When a molecule of acetylene decomposes and releases its great latent energy, the energy activates neighboring molecules and sets up a chain reaction. The whole process is aided by heat and pressure: the higher the temperature, the more likely it is that decomposition will start; the closer the molecules are to one another, the more rapid is the chain reaction. In a large space occupied only by acetylene, the chain of decomposition, once started, is so rapid that it leads almost instantaneously to an explosion. But if the space is shared by a stable gas such as nitrogen or carbon dioxide, the energy released by the decomposing acetylene molecules is partly absorbed by the inert molecules of the diluent, and its impact on other acetylene molecules is thereby cushioned. The chain reaction is either stopped entirely or slowed sufficiently to prevent an explosion.

By diluting acetylene in this way, Reppe was able safely to apply temperatures up to 200 degrees Centigrade and pressures of five and six atmospheres—remarkably high for the usual handling of this gas. Under these conditions, and with the help of alkaline catalysts such as potassium hydroxide, Reppe made acetylene react with other materials in some new ways. One of these processes, called vinylation, combined acetylene with alcohols to form vinyl ethers—a versatile class of raw materials used in the manufacture of transparent and surgical tapes, dipped rubber goods, adhesives for metals, lacquers, and sulfa drugs. (The vinyl ethers can also be made from ethylene, but by a process that requires three steps instead of one.) Reppe also reacted acetylene with a phenol, a relative of carbolic acid, and thereby produced a resin called Koresin which played an important role as a tackifier in the German wartime synthetic rubber industry.

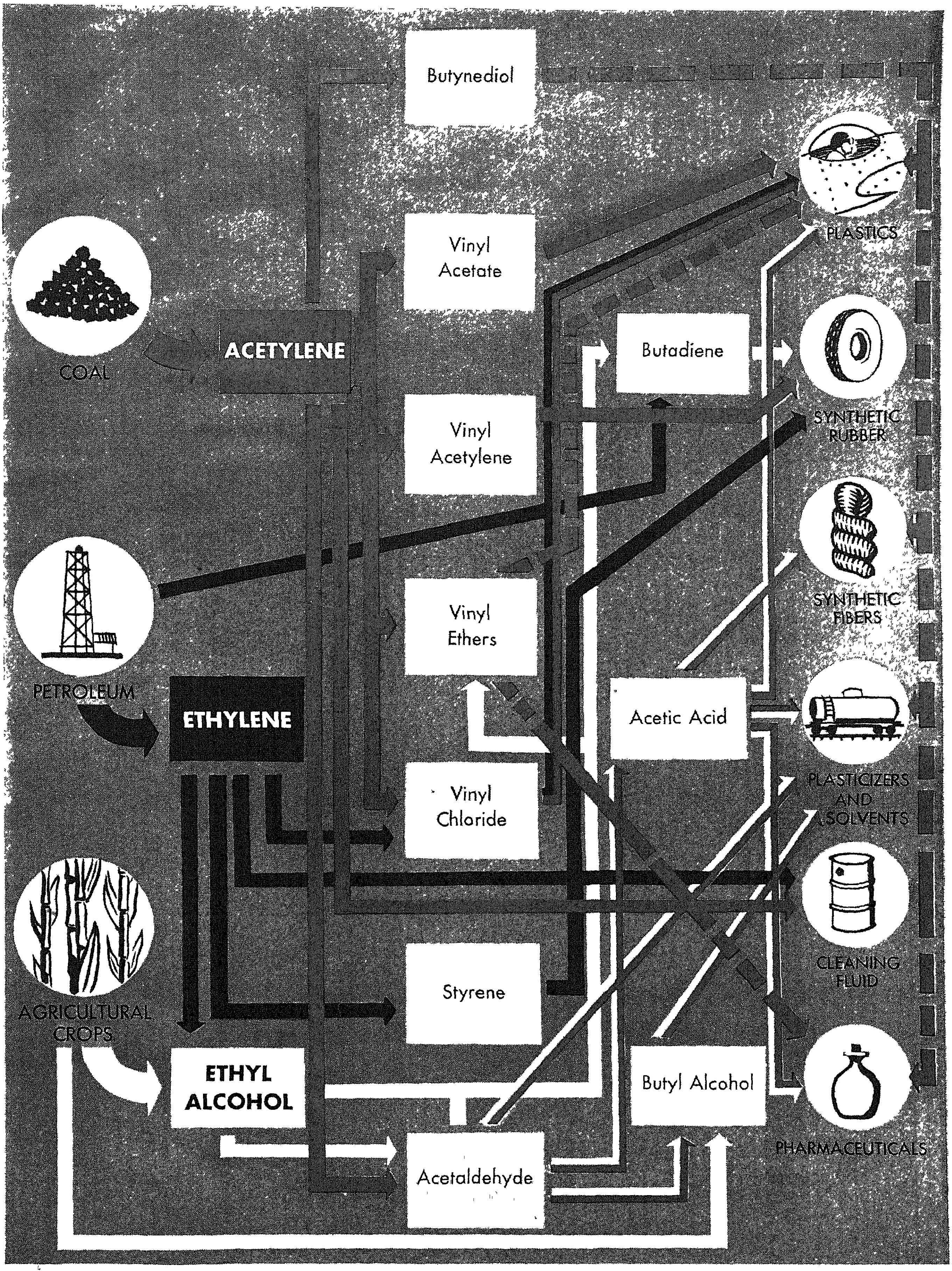
Reppe now set out on a second method of controlling acetylene which was to yield even more important results. His objective was to take advantage of the unusual property of acetylene mentioned earlier in this article—the mobility of the two hydrogen atoms which are loosely held at the ends of the acetylene molecule. It was known that these two atoms could readily be replaced by reactive metals such as sodium, and that the resulting compound would react with certain other compounds such as acetone to form new substances. But there was a difficulty: normally these reactions took place only in the complete absence of water—a requirement that made the process too expensive for industrial use.

Reppe found that if the acetylene gas was heated and compressed the reactions would work even in the presence of water. The problem of handling the hot acetylene, however, was more formidable than in the preparation of the vinyl ethers, for the new process demanded concentrated acetylene; it could not be diluted with an inert gas.

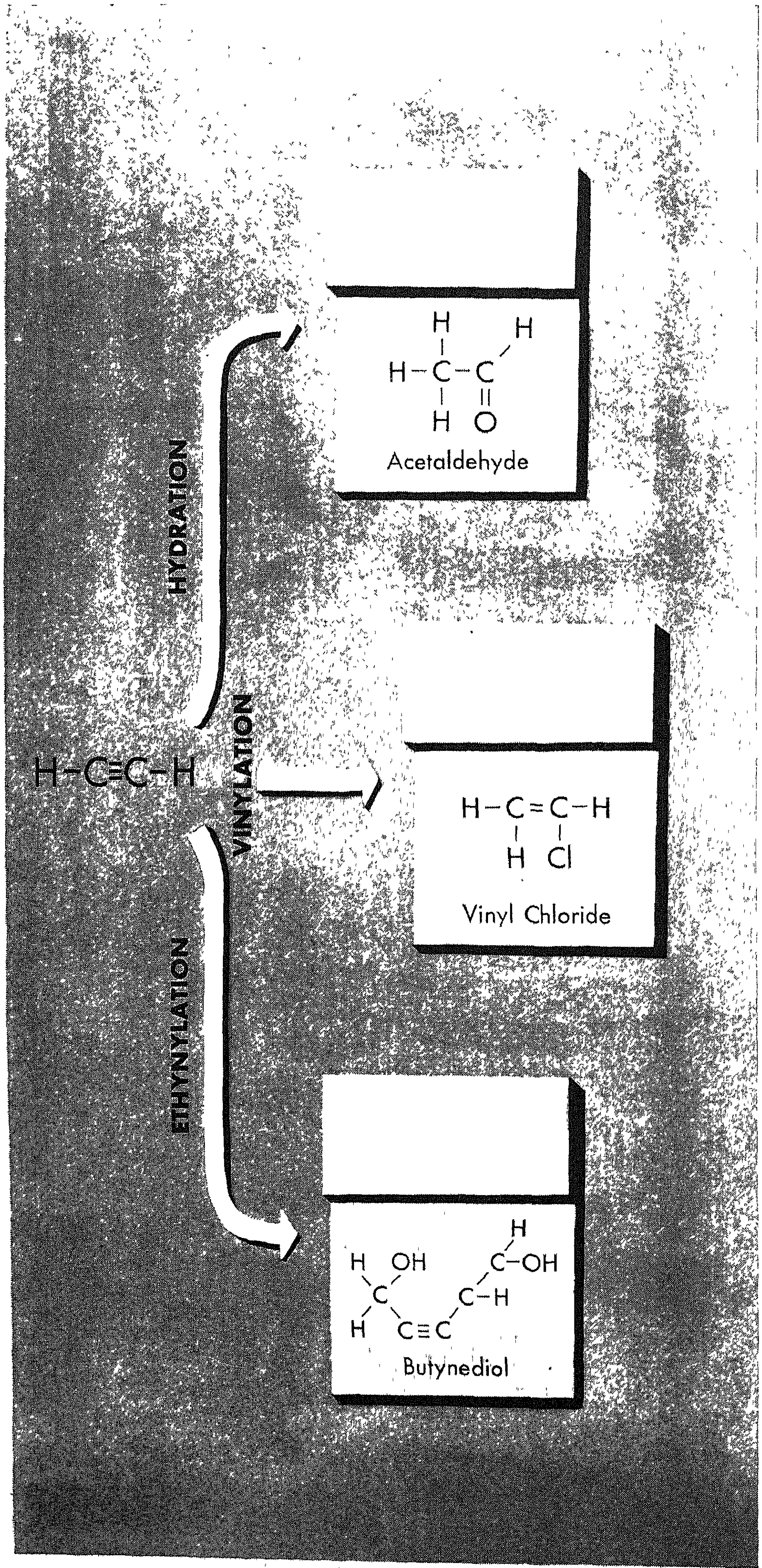
This problem was solved by extension of another one of the routine procedures long established in the industry for the safe handling of acetylene: the narrowing of all spaces in which acetylene is confined. The conduit tubes through which the hot gas was conducted were reduced to a diameter of half an inch or less, or they were filled with bundles of tubes, and the spaces in the large vessels where the reactions took place were crammed with small tubular rings of metal or porcelain. The effect of this breakup of the spaces was to slow down the propagation of any explosion wave that might be started by decomposition of the acetylene; when decomposition began, the tubes and rings, like the molecules of a diluent gas, absorbed enough of the energy of decomposing molecules to arrest the chain reaction and prevent an explosion. After one disastrous blast, the Farben group succeeded in controlling the chain reaction so that it only made the equipment get red hot.

To make the whole process work, the Germans also had to use copper acetylide as a catalyst. This made U. S. chemists shudder when they learned of it, for copper acetylide is normally even more prone to explode than compressed acetylene. Reppe found, however, that treatment of the compound with acetylene under precisely controlled conditions made the catalyst safe enough.

The chemical process which Reppe developed from these experiments is known as ethynylation. A new technique in industry, it cannot be applied to refinery gases such as ethylene, and it therefore greatly enhances the value and possibilities of



ACETYLENE, other things being equal, could largely replace ethylene and ethyl alcohol in the huge U. S. aliphatic chemical industry. Each, respectively, is the principal intermediate between coal, oil or agricultural materials and finished products. Dotted red lines indicate processes developed by the Germans. Lines shared by acetylene and either of the other intermediates show that either one is used for this particular route.



THREE PROCESSES variously utilize triple bond between carbon atoms of acetylene molecule (*left*). Hydration reduces triple bond to single; vinylation to double. Ethynylation preserves energy-rich triple bond.

acetylene. The reaction was carried out with formaldehyde (CH_2O) in water solution. In the first step of this reaction, one of the active hydrogen atoms in acetylene attaches itself to the oxygen atom of the formaldehyde, and acetylene's two carbon atoms join with the one in formaldehyde. The product, $H-C{\equiv}C-CH_2-OH$, is propargyl alcohol, a new chemical which until recently was known only in the laboratory. This compound reacts with another molecule of formaldehyde to form 1,4-butynediol, a product containing a chain of four carbon atoms. And butynediol is like a traffic circle from which radiate scores of great highroads in chemistry.

The Germans followed some of these roads vigorously. By hydrogenation of butynediol they made 1,4-butanediol, a glycol which promises to become as important for industrial synthesis as ethylene glycol. From butynediol they also produced butadiene for synthetic rubber tires, and adiponitrile for making nylon. They also explored other acetylene reactions; using acetylene, carbon dioxide and water, for example, they developed a new process for making acrylic acid, an important chemical building block for such products as textile sizings, thickeners and adhesives. From acetylene and hydrocyanic acid, the Germans worked out another way to arrive at acrylonitrile, the parent material for Buna-N rubber and the new synthetic fiber Orlon, recently announced by du Pont.

Thus acetylene became the *sine qua non* of Germany's chemistry. In 1942 she produced 7.2 billion cubic feet of it for chemical purposes.

Large as the German enterprise was, it had barely begun to explore the beckoning new roads. The U. S. chemical industry is now about to take up these explorations where the Germans left off. General Aniline and Film, as an offshoot of I. G. Farben, presumably is in the best position to put the German techniques to work—and to jump off from them into new investigations. G. A. F. owns the U. S. rights to Reppe's vinylation and ethynylation processes.

For the present, the chief output of G. A. F.'s pilot plant at Grasselli will be the vinyl ethers, employing the Reppe vinylation process on which the company has been conducting laboratory work since 1945. However, vinyl ethers, like other vinyl compounds, can be and are derived from ethylene. Chemists, therefore, are more interested to see what will come of Reppe's high-pressure ethynylation process.

For its work in this field, G. A. F. has installed equipment on the German model, a 60-foot steel tower, five feet in diameter, built to withstand pressures up to 100 atmospheres, in case anything goes wrong with the acetylene reaction inside. From this process the company hopes to obtain not only a great variety of goods in bulk

but also some fine biologicals. An example is polyvinyl pyrrolidone, which Reppe derived from butynediol The water solution of this chemical, which the Germans called Periston, was extensively used by them during the war as a substitute for blood plasma. G. A. F. is now supplying samples for evaluation in the U. S.

Aside from these processes, two other aspects of acetylene are currently intriguing U. S. chemists. One is a curiosity called cyclooctatetraene, a ring compound which Reppe created during the war by condensing four molecules of acetylene The ring thus formed is similar to that of benzene, but has eight sides instead of six While no one has given this molecule much study, it is considered theoretically capable of forming the basis of an industry nearly as important as the coal tar industry, which is built around benzene.

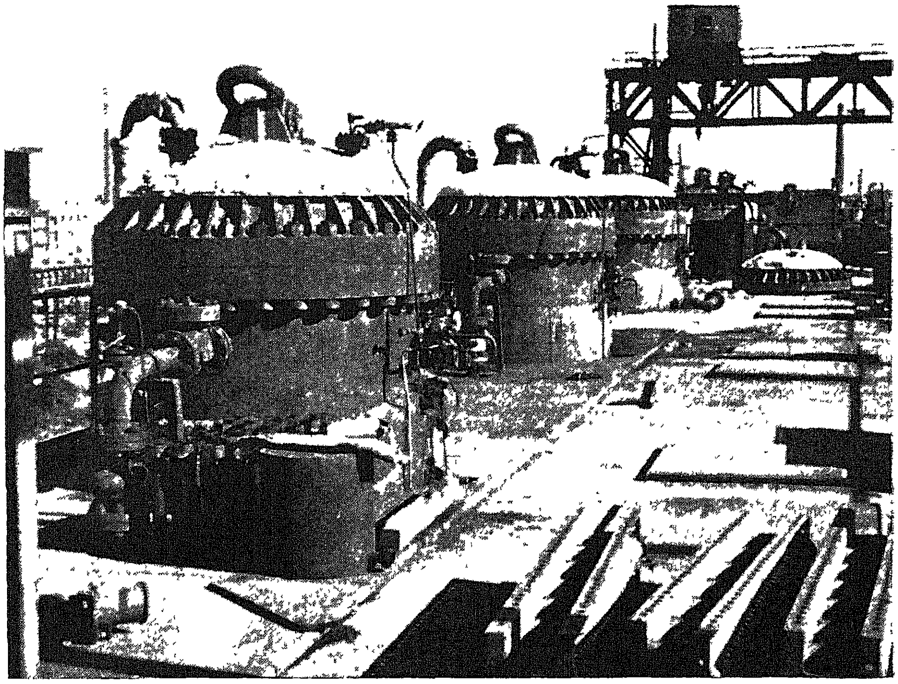
The other new idea is the possibility of developing acetylene processes that depend on catalysts rather than heat and pressure. Of interest in this direction is the work of a chemical engineer, A. Brothman, of New York, who has developed a number of promising catalyst-based reactions. One is a three-step reaction of acetylene with acetone which yields methyl-methacrylate, the clear plastic used in aircraft windows, navigation domes and gun turrets.

How much further chemists will go with the excitable hydrocarbon that the two aluminum-hunters made in their electric furnace half a century ago depends of course on a variety of factors, not all of them scientific. Despite acetylene's wide possibilities, it seems unlikely that the chemical will become as important in the U. S. as it was in Germany, for the U. S has a great wealth of other materials which are more readily accessible to exploitation. For 20 years U. S. chemistry has increasingly been based on petroleum.

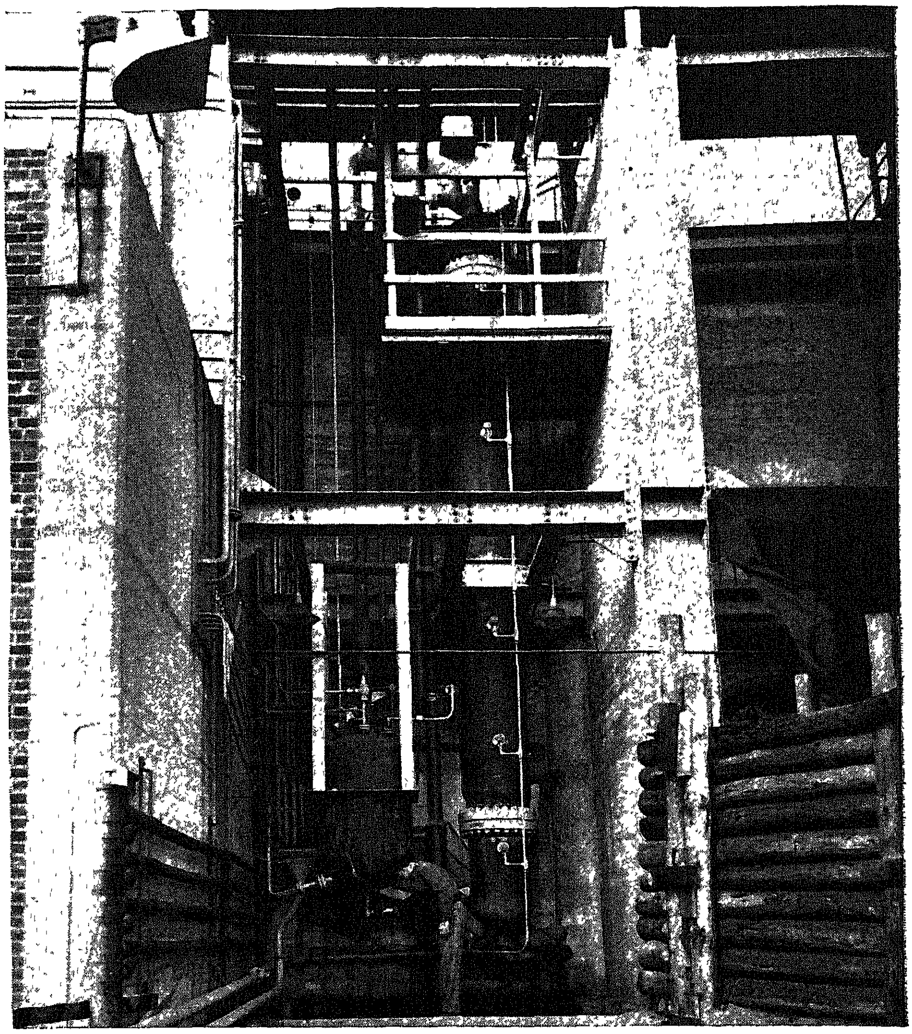
This growing dependence on petroleum, however, raises the question of what the chemical industry will do should U. S. oil reserves run out If world conditions make it difficult or uneconomic to get petroleum from abroad, American chemistry in all likelihood will turn to coal as the basic raw material. In that event, acetylene, from carbide, would become the building block for a large proportion of the organic intermediates, sharing the market with other intermediates derived from coal via the Fischer-Tropsch process and hydrogenation.

In any case, the new development of the chemistry of acetylene adds to the assurance that, despite any possible dearth of petroleum, the U. S. chemical industry will be able to fill the needs of the nation for centuries to come.

Herbert Yahraes was the author of Labrador Iron, *which appeared in the November issue of this magazine.*



MASSIVE VESSELS were built by I. G. Farben in Ludwigshaven, Germany, for the ethynylation of acetylene. Vessels are strong enough to withstand any pressures short of explosion developed by the breakdown of acetylene.



SMALLER VESSEL at the General Aniline and Film pilot plant is 60 feet high, five feet in diameter, and built to withstand pressures up to 100 atmospheres per square inch. It is first such vessel constructed in U. S.

The Oedipus Myth

Sigmund Freud felt that it reflected a basic structure of human relationships. The author presents a new theory of the Oedipus complex based on Sophocles' great dramas

by Erich Fromm

In one of his basic works, *The Interpretation of Dreams*, Sigmund Freud wrote:

If the Oedipus Rex *is capable of moving a modern reader or playgoer no less powerfully than it moved the contemporary Greeks, the only possible explanation is that the effect of the Greek tragedy does not depend upon the conflict between fate and human will, but upon the peculiar nature of the material by which this conflict is revealed. There must be a voice within us which is prepared to acknowledge the compelling power of fate in the* Oedipus. . . . *And there actually is a motive in the story of King Oedipus which explains the verdict of this inner voice His fate moves us only because it might have been our own, because the oracle laid upon us before our birth the very curse which rested upon him. It may be that we are all destined to direct our first sexual impulses toward our mothers, and our first impulses of hatred and violence toward our fathers; our dreams convince us that we are. King Oedipus, who slew his father Laius and wedded his mother Jocasta, is nothing more or less than a wish-fulfillment—the fulfillment of the wish of our childhood. But we, more fortunate than he, in so far as we have not become psychoneurotics, have since our childhood succeeded in withdrawing our sexual impulses from our mothers, and in forgetting our jealousy of our fathers. We recoil from the person for whom this primitive wish of our childhood has been fulfilled with all the force of the repression which these wishes have undergone in our minds since childhood. As the poet brings the guilt of Oedipus to light by his investigation, he forces us to become aware of our own inner selves, in which the same impulses are still extant, even though they are suppressed . . . after their unveiling we may well prefer to avert our gaze from the scenes of our childhood.*

The concept of the Oedipus complex, which Freud so beautifully presents in the passage just quoted, became one of the cornerstones of his psychological system. He believed that this concept was the key to an understanding of history and of the evolution of religion and morality. His conviction was that the Oedipus complex constituted the fundamental mechanism in the development of the child, and he maintained that the complex was both the cause for psychopathological development and the "kernel of neurosis."

Freud assumed that the male child at the age of four or five is sexually attracted to his mother; hence he is jealous of his father, who appears to him as a superior, threatening rival; hence he becomes intensely afraid of his father and specifically afraid of being castrated. Since this fear becomes too intense for comfort and security, the boy changes his aim. He gives up the mother as an object of his sexual strivings and identifies himself with the father. In doing so he overcomes his fear, and at the same time his own masculine development is strengthened by the fact that he now wants to be like his father Freud assumed that a particular identification takes place—namely, with the father's conscience, his commands, and his prohibitions—and that thus the bases for the development of conscience in the boy are laid.

> **EDITOR'S NOTE**
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> This article is an abridged version of a chapter in *The Family: Its Functions and Destiny*, edited by Ruth Nanda Anshen, which will be published next month by Harper & Brothers.

In normal development, the Oedipus complex results in the strengthening of masculine characteristics and in the growth of conscience. The boy's attachment to the mother is transferred later on to girls of his own age, although his choice of a love object may remain determined to some extent by the image of the mother. In the neurotic development, the tie with the mother is not severed. She herself, or women who resemble her, remain the exclusive love objects. In the latter case, the relationship to the mother surrogate retains the qualities that were characteristic of the little boy's attachment to his mother—dependency, lack of responsibility, and the need to be taken care of. Simultaneously, rivalry with the father or father surrogates, and hate and fear of them, remain active too.

Freud's concept of the Oedipus complex was a result of clinical observations and theoretical speculation, and so it must have been very gratifying to him that the classic myth of Oedipus seemed to be not only a symbolic expression but also a confirmation of his theory. Freud knew the Oedipus myth from Sophocles' tragedy *King Oedipus*. This tragedy relates that an oracle has told Laius, the King of Thebes, and his wife, Jocasta, that if they should have a son this son would kill his father and marry his mother. When a son, Oedipus, is born to them, Jocasta decides to escape the fate predicted by the oracle by killing the infant. She gives Oedipus to a shepherd who is to abandon the child in the woods with his feet bound so that he will die. But the shepherd, taking pity on the child, gives the infant to a man in the service of the King of Corinth, who in turn brings him to his master. The King adopts the boy, and he grows up believing that he is the King's real son.

Oedipus is told by the oracle in Delphi that it is his fate to kill his father and to marry his mother. He decides to avoid this fate by never going back to his supposed parents in Corinth. On his way from Delphi, he engages in a violent argument with an old man riding in a carriage, loses his temper, and kills the man and his servant without knowing that he has slain his father, the King of Thebes.

His wanderings then lead him to Thebes. There a Sphinx is devouring the young men and women of the city. She will cease only if someone finds the answer to a riddle she asks: "What is it which first goes on four, then on two, and eventually on three?" The city of Thebes has promised that anyone who can solve the riddle and free the city from the Sphinx will be made king, and will be given the King's widow as his wife. Oedipus discovers the answer—which is *man*, who as a child walks on all four, as an adult on two, and in his old age on three (with a cane). The Sphinx throws herself into the ocean, the city is saved from calamity, Oedipus becomes king and marries Jocasta, his mother.

After Oedipus has reigned happily for some time, the city is ravaged by a plague

that kills many of its citizens The seer Teiresias reveals that the plague is punishment for the twofold crime which Oedipus has unknowingly committed, that of patricide and incest. Oedipus, after having tried desperately not to see this truth, blinds himself when he is compelled to see it, and Jocasta commits suicide.

The question is whether Freud was right in assuming that this myth confirms his view that unconscious incestuous drives and resulting hate against the father-rival are an intrinsic part of any male child's equipment. Indeed, it does seem as if the myth confirmed Freud's theory. If we examine the myth more closely, however, doubts arise. The most pertinent is this: If Freud's interpretation is right, we should expect the myth to tell us that Oedipus met Jocasta without knowing that she was his mother, fell in love with her, and then killed his father, again unknowingly But there is no indication whatsoever in the myth that Oedipus is attracted by or falls in love with Jocasta. The only reason we are given for Oedipus' marriage to Jocasta is that she goes with the throne. Indeed, in older versions of the story, there is usually no mention of a prediction by the oracle that the son will marry his mother Should we believe that a myth which deals primarily with an incestuous relationship between mother and son can so completely ignore the element of attraction between the two?

From a consideration of *King Oedipus* alone, no definite answer can be given. But we are at least in a position to formulate a hypothesis, namely that the myth has to be understood as a symbol, not of the incestuous tie between mother and son, but of the rebellion of the son against the authority of the father in the patriarchal family; that the marriage of Oedipus and Jocasta is only a secondary element, only one of the symbols, of the victory of the son who takes over his father's place and with it all its privileges

THE validity of this hypothesis can be tested by examining the whole Oedipus myth, particularly in the form presented by Sophocles in the two other parts of his trilogy, *Oedipus at Colonus* and *Antigone*.

In *Oedipus at Colonus* we find Oedipus near Athens at the grove of the Eumenides shortly before his death. After having blinded himself, Oedipus remained in Thebes. Creon, his uncle, who succeeded him as ruler, after a time exiled him. Oedipus' two daughters, Antigone and Ismene, accompanied him into exile; but his two sons, Eteocles and Polyneices, refused to help their blind father. After his departure, the two brothers strove for possession of the throne. Eteocles won; but Polyneices, refusing to yield, sought to conquer the city with outside help and to wrest the power from his brother. In *Oedipus at Colonus* we see him approach his father, begging his forgiveness and asking his assistance. But Oedipus is relentless in hatred toward his sons. In spite of the passionate pleading of Polyneices, supported by Antigone, he refuses forgiveness

In *Antigone* we find another father-son conflict as one of the central themes of the tragedy. Here Creon, the representative of the authoritarian principle in state and family, is opposed by his son, Haemon, who reproaches him for his ruthless despotism and his cruelty against Antigone. Haemon tries to kill his father and, failing to do so, kills himself.

We find that the theme which runs through all three tragedies is the conflict between father and son. In *King Oedipus* this conflict is expressed by the fact that

OEDIPUS IS ENTHRONED as King of Thebes with Jocasta as his queen. He does not know that a stranger he has slain is his father, nor that Jocasta is his mother. These events Freud interpreted as the fulfillment of a wish of childhood. The drawing is made in the style of the Greek decorations contemporaneous with Sophocles.

Oedipus kills his father, Laius—the significance of which is not diminished by Oedipus' ignorance. In *Oedipus at Colonus* Oedipus gives vent to his intense hatred of his sons, and in *Antigone* we find the same hatred again between Creon and Haemon. There is no problem of incest in the relationship of Oedipus' sons to their mother nor in the relationship between Haemon and his mother, Eurydice If we interpret *King Oedipus* in the light of the whole trilogy, the assumption seems plausible that the real issue in *King Oedipus,* too, is the conflict between father and son and not incest.

The question arises as to how we may explain this conflict. One clue is given in *Antigone*, by the rebellion of Haemon against Creon Creon represents the authoritarian principle both in the family and the state, and it is against this type of authority that Haemon rebels. An analysis of the whole Oedipus trilogy will show that the struggle against paternal authority is its main theme and that the roots of this struggle extend far back into the ancient struggle in both family and religion between the patriarchal and matriarchal systems of society. Oedipus, Haemon, and Antigone are representatives of the matriarchal world who attack a social and religious order based on the powers and privileges of the father, represented by Laius and Creon.

This proposition is based on the famous analysis of Greek mythology by the Swiss scholar J. J. Bachofen. It is necessary, therefore, briefly to consider the principles of Bachofen's theory in order to lay the foundations for the writer's interpretation of the Oedipus myth

In his *Mutterrecht* (mother right). published in 1861, Bachofen suggested that in the beginning of human history sexual relations were promiscuous, as a result only the mother's parenthood was unquestionable. To her alone could consanguinity be traced. She was, therefore, the authority and lawgiver—in the family group, in society and in religion. On the basis of his analysis of religious documents in Greek and Roman antiquity, Bachofen came to the conclusion that the religion of the Olympian gods was preceded by a religion in which goddesses, motherlike figures, were the supreme deities.

Bachofen assumed that in a long historical process men subdued women, and succeeded in making themselves the rulers in a social hierarchy. The patriarchal system thus established is characterized by monogamy (at least so far as women are concerned), by the authority of the father in the family, and by the central role of men in a hierarchically organized society. Instead of the mother goddesses, male gods became the supreme rulers of man.

Bachofen showed that the difference between the matriarchal and patriarchal orders extended to social and moral principles. Matriarchal culture is characterized by an emphasis on ties of blood, ties to the soil, and a passive acceptance of all natural phenomena. Patriarchal society, in contrast, is characterized by respect for man-made law, by the predominance of rational thought, and by man's effort to change natural phenomena. So far as these principles are concerned, the patriarchal culture constituted progress beyond the matriarchal culture. In other respects, however, the matriarchal principles were superior to the victorious patriarchal ones In the matriarchal concept all men are equal, since they are all the children of mothers and each one a child of Mother Earth. A mother loves all her children equally and without conditions, since her love is based on the fact that they are her children and not on any particular merit or achievement; the aim of life is the happi-

BLIND OEDIPUS is accompanied into exile by his daughters, Ismene and Antigone. Sons remain behind.

ness of men, and there is nothing more important than human existence and life. The patriarchal system, on the other hand, recognizes obedience to authority as its main virtue.

"The relationship through which mankind has first grown into civilization, which is the beginning of the development of every virtue and of the formation of the nobler aspects of human existence," says Bachofen, "is the matriarchal principle, which becomes effective as the principle of love, unity, and peace. . . Its principle is that of universality, whereas the patriarchal principle is that of restrictions. . . . The idea of the universal brotherhood of man is rooted in the principle of motherhood, and this idea vanishes with the development of patriarchal society."

Bachofen's theory was strengthened by the work of a 19th-century American scholar, L. H. Morgan. Independently, Morgan came to the conclusion that the kinship system of the American Indians—similar to that found in Asia, Africa, and Australia—was based on the matriarchal principle, and that the most significant institution in such cultures, the gens, was organized in conformity with the matriarchal principle. Morgan's conclusions about principles of value in a matriarchal society were quite similar to Bachofen's He proposed that the future form of civilization "will be a repetition—but on a higher level—of the principles of liberty, equality, and fraternity which characterized the ancient gens." Both Bachofen's and Morgan's theories of matriarchy were disputed, if not entirely ignored, by most anthropologists. The violence of the antagonism against the theory of matriarchy arouses the suspicion that the criticism was not entirely free from an emotionally founded prejudice against an assumption so foreign to the thinking and feeling of our patriarchal culture. There is little doubt that many single objections to the matriarchal theory are justified and that it is not tenable in the form in which it was presented by Bachofen. Nevertheless, Bachofen's main thesis, that we find an older layer of matriarchal religion underneath the more recent patriarchal religion of Greece, seems to me to have been established by him beyond any doubt.

All this bears upon our hypothesis that the hostility between father and son, which is the theme running through Sophocles' trilogy, is to be understood as an attack against the victorious patriarchal order by the representatives of the defeated matriarchal system.

In the various Greek formulations of the Oedipus myth upon which Sophocles built his tragedy, the figure of Oedipus was always connected with the cult of the earth goddesses, the representatives of matriarchal religion. Oedipus' connection with the Sphinx seems also to point to a connection between Oedipus and the matriarchal principle as it is described by Bachofen If we look closely at the Sphinx's riddle, we are struck by the insignificance of the riddle in comparison with the reward for its solution. Any clever boy of twelve might guess that that which goes first on four, then on two, and eventually on three is man. Why should the right guess be proof of such extraordinary powers as to make their possessor the savior of the city? The answer to this question lies in an analysis of the riddle's real meaning, an analysis which must follow the principles of interpretation of myths and dreams developed by Bachofen and Freud. They showed that often the most important element in a dream or myth may appear to be an insignificant part of the myth itself, while the part of the myth that appears to have the main accent is only a minor element in its real meaning.

Applying this principle to the Sphinx myth, but with an interpretation different from the one Bachofen or Freud gave it, it would seem that the important element in the riddle is not the part that is stressed

in the manifest formulation of the myth, namely the riddle itself, but the answer to the riddle: *man*. If we translate the Sphinx's words from symbolic into overt language we hear her say He can save mankind who knows that man himself is the most important answer man can give to the most difficult question with which he is confronted. This emphasis on the importance of man is part of the principle of the matriarchal world as Bachofen described it

One element in the myth and in Sophocles' *King Oedipus* seems to contradict our hypothesis—the figure of Jocasta On the assumption that she symbolizes the motherly principle, and that the explanation suggested here is correct, the question arises why the mother also is destroyed instead of being victorious But examination of the role of Jocasta shows that it not only does not contradict our hypothesis, but tends to confirm it. Jocasta's crime is that of not having fulfilled her duty as a mother; she is ready to kill her child in order to save her husband. This, from the standpoint of patriarchal society, is a legitimate decision, but from the standpoint of matriarchal society and matriarchal ethics it is the unforgivable crime. By committing this crime, it is she who starts the chain of events that eventually leads to her own end and to her husband's and son's destruction. The myth explains the reasons for the downfall of matriarchy It proposes that the mother by violating her paramount duty brought about her own destruction

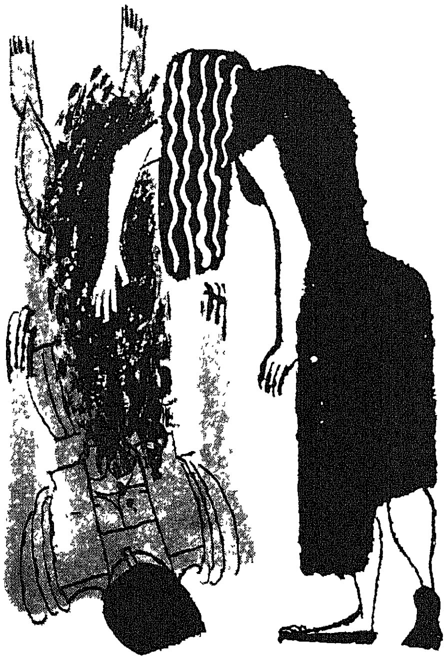
In *Oedipus at Colonus* we see the blind Oedipus accompanied by his two daughters arriving near Athens, close to the grove of the goddesses of the earth. The oracle has prophesied that if Oedipus is buried in this grove he will protect Athens from invasion by her enemies. Oedipus makes this known to Theseus, the King of Athens. Theseus gladly accepts Oedipus' offer that he become the posthumous benefactor of Athens Oedipus retreats into the grove of the goddesses and dies in a mysterious way not known to anybody but Theseus

Who are these goddesses? Why do they offer a sanctuary to Oedipus? What does the oracle mean by telling us that Oedipus, in finding his last home in this grove, reverts to his role of savior and benefactor?

In *Oedipus at Colonus* the answer is given to the first question, that of the identity of the goddesses. Oedipus implores them, saying:

Queens of dread aspect, since your seat is the first in this land whereat I have bent the knee, show not yourselves ungracious to Phoebus or to myself; who, when he proclaimed that doom of many woes, spake of this as a rest for me after long years—on reaching my goal in a land where I should find a seat of the Awful Goddesses, and a hospitable shelter. . . .

Oedipus calls the goddesses "Queens of dread aspect" and "Awful Goddesses." Why are they "dreadful" and "awful," since to him they are the goddesses of his last resting place and those who will eventually give him peace? The answer can be found only in a principle of interpretation, valid for both myths and dreams, which has been recognized by Bachofen and Freud. If an element appearing in a myth or in a dream belongs to a much earlier phase of development, and is not part of the conscious frame of reference at the time of the final formulation of the myth, this element often carries with it the quality of dread and awfulness. Touching upon something hidden and taboo, the conscious mind is affected by a fear of a particular kind—the fear of the unknown and the mysterious. The "Awful Goddesses" which are mentioned by Oedipus here represent the defeated matriarchal system.



ANTIGONE scatters earth over the corpse of her brother. Later Antigone is buried alive in cave by Creon.

Goethe, in one of the least understood passages of *Faust*, has treated of the dread of the mysterious mothers in a spirit very similar to that of Sophocles' *Oedipus at Colonus*. Mephistopheles says:

Unwilling I reveal a loftier mystery—
In solitude are throned the Goddesses,
No space around them. Place and Time still less;
Only to speak of them embarrasses;
They are the Mothers!

Faust (*terrified*):

Mothers!

Mephistopheles

Hast thou dread?

Faust:

The Mothers! Mothers!—a strange word is said.

Mephistopheles:

It is so. Goddesses, unknown to ye,
The Mothers, named by us unwillingly.
Delve in the deepest depth must thou, to reach them.
It is thine own fault that we for help beseech them.

Here too, as in Sophocles' tragedy, the feeling of dread and terror is bound up with the mere mentioning of the goddesses. They belong to an ancient world which now is banned from the light of day, from consciousness.

As we see from this short passage, Goethe anticipated Bachofen's theory; according to the diary of Eckermann, Goethe mentioned that in reading Plutarch he found "that in Grecian antiquity the Mothers are spoken of as Goddesses" This passage in *Faust* has appeared enigmatic to most commentators who tried to explain the mothers as a symbol of Platonic ideas, the formless realm of the inner world of spirit, and so forth. Indeed, it must remain an enigma unless one understands it in the light of Bachofen's findings

We have already pointed to the fact that the main theme of the Oedipus trilogy, the conflict between father and son, finds its full expression in *Oedipus at Colonus*; here the hate between father and son is not, as in *King Oedipus*, unconscious; indeed, here Oedipus is very much aware of his hate against his sons, whom he accuses of having violated the eternal law of nature. There is no indication in *Oedipus at Colonus* that the hostility of Oedipus' sons against their father has any connection with the incest motif. The only motivation which we can find is their wish for power and the rivalry with their father.

HOW different is the end of *Oedipus at Colonus* from that of *King Oedipus!* In the latter the fate of Oedipus seemed to be sealed as that of the tragic criminal whose crime removes him forever from his family and from his fellow men, destined to be an outcast, abhorred though perhaps pitied by everyone. In the former he dies as a man surrounded by two loving daughters and by new friends whose benefactor he has become, not with a feeling of guilt but with a conviction of his right, not as an outcast but as one who has eventually found his home—with the earth and the goddesses who rule there. The tragic guilt which had pervaded *King Oedipus* has now been removed, and only one conflict has remained as bitter and unsolved as ever—that between father and son.

The conflict between the patriarchal and matriarchal principles is still the theme in *Antigone*, the third part of the trilogy. Here the figure of Creon represents the principle of the supremacy of the law of the state over ties of blood, of obedience to authority over allegiance to the natural law of humanity. Antigone represents the matriarchal principle and thus is the uncompromising adversary of Creon. He must defeat Antigone in order to uphold patriarchal authority and with it his own virility. Haemon, Creon's son,

represents the same principles as Antigone. Although he tries at first to appease and persuade his father, he openly declares his opposition when he sees that his father will not yield.

The end of the tragedy carries the action to the point of final decision. Creon has Antigone buried alive in a cave—a symbolic expression of her connection with Mother Earth The seer Teiresias, who in *King Oedipus* was instrumental in making Oedipus aware of his crime, appears again, this time to make Creon aware of his. Stricken by panic. Creon gives in and tries to save Antigone. He rushes to the cave where she is entombed, but Antigone is already dead. Haemon tries to kill his father; when he fails, he takes his own life. Creon's wife, Eurydice, upon hearing the fate of her son, kills herself, cursing her husband as the murderer of her children. Creon recognizes the complete collapse of his world and the defeat of his principles He admits his own moral bankruptcy, and the play ends with his confession.

WE are now in a position to answer the questions that we raised at the beginning. Is the Oedipus myth as presented in Sophocles' trilogy centered on the crime of incest? Is the murder of the father, as Freud believed, the symbolic expression of a hate resulting from jealousy? Though the answer is doubtful at the end of *King Oedipus*, it is hardly doubtful at the end of *Antigone*. Not Oedipus but Creon is defeated in the end, and with him the principle of authoritarianism, of man's domination over men, the father's domination over his son, and the dictator's domination over the people.

Our interpretation needs to be supplemented, however, by another consideration. Although the conflict between Oedipus, Antigone and Haemon on the one side against Creon on the other contains a memory of the conflict between patriarchal and matriarchal principles, it must also be understood in terms of the specific political and cultural situation in Sophocles' time and of his reactions to that situation.

The Peloponnesian War, the threat to the political independence of Athens, and the plague which ravaged the city at the beginning of the war, had helped to uproot the old religious and philosophical traditions. Indeed, attacks against religion were not new, but they reached a climax in the teachings of Sophocles' Sophist adversaries. He was opposed particularly to those in the extreme wing of the Sophists who not only acclaimed despotism exercised by an intellectual elite, but also upheld unrestricted selfishness as a moral principle. The ethics of egotistical supermen and the amoral opportunism of this wing of the Sophists were the very opposite of Sophocles' philosophy. In Creon Sophocles created a figure representing this school of sophism, and Creon's speeches resemble the Sophist pattern even in style and expression.

In his argument against the Sophists, Sophocles gave new expression to the old religious traditions of the people with their emphasis on love, equality and justice. The German scholar Wilhelm Schmid has observed: "The religious attitude of Sophocles . is primarily concerned not with the official religion of the state but with those helpful secondary powers which always were closer to the faith of the masses than the aristocratic Olympians and to whom the people turned again in the dangers of the Peloponnesian War." These "secondary powers," which were different from the "aristocratic Olympian" gods, are easily identified as the goddesses of the matriarchal world.

We see, then, that Sophocles' views expressed in the Oedipus trilogy are to be understood as a blend of his opposition to contemporary sophism and his sympathy for the old non-Olympian religious ideas In the name of both he proclaimed the principle that the dignity of man and the sanctity of human bonds must never be subordinated to inhuman and authoritarian claims of the state or to opportunistic considerations.

Thus far we have been concerned only with the interpretation of the Oedipus myth and not with Freud's clinical description of the Oedipus complex. Quite apart from the question of whether Freud's clinical description is correct, we arrive at the result that the complex characterized by a boy's incestuous strivings toward his mother and his resulting hostility against his father is wrongly called an Oedipus complex. There is a complex frequently found in patriarchal cultures, however, that fully deserves to be called an Oedipus complex: namely, the rebellion of the son against the pressure of the father's authority—an authority rooted in the patriarchal, authoritarian structure of society.

The child does not meet society directly at first; he meets it through the medium of his parents, who in their character structure and methods of education represent the social structure, and are, as it were, the psychological agency of society. What, then, happens to the child in his relationship to his parents? Often he meets through them the kind of authority that prevails in a patriarchal society, and this kind of authority tends to break his will, his spontaneity, his independence. But since man is not born to be broken, the child fights against the authority represented by his parents; he fights not only for his freedom from pressure but also for his freedom to be himself, a full-fledged human being and not an automaton.

In this struggle some children are more successful than others; most of them are defeated to some extent in their fight for freedom. The ways in which the defeat is brought about are manifold, but, whatever they are, the scars left in the child's unsuccessful fight against irrational authority are to be found at the bottom of every neurosis. Such a scar is represented in a syndrome of which the most important features are a weakening or paralysis of the individual's originality and spontaneity, a weakening of the self and the substitution of a pseudo self in which the feeling of "I am" is dulled and replaced by the experience of self as the sum total of expectations others have about the self, and finally a substitution of heteronomy for autonomy.

Does our interpretation of the Oedipus myth and of the Oedipus complex imply that Freud's theory was without foundation?

Freud observed three facts, and each of these observations was valid. We now propose to show that the unified theoretical interpretation which he gave to his three observations was fallacious, and that the progress of psychological theory lies in the direction of seeing the observed phenomena afresh and interpreting them differently. The facts which Freud observed were the following:

First, he noted the presence of sexual strivings in children Although this phenomenon has found wide recognition today, at the beginning of the century it was a revolutionary discovery which tremendously advanced our knowledge of child psychology.

Second, Freud observed that the ties by which children are bound to their parents are often not severed at a time when, in the normal development, they should be severed and the child should become independent. He saw that this irrational "fixation" of children to their parents is to be found in all neuroses, and is one of the causes for the development of neurotic symptoms and neurotic character traits The significance of this discovery can hardly be overestimated. The more data we collect, the more it becomes apparent that the peculiar lack of maturity and self-assertion, the emotional and intellectual distortions so characteristic of every neurosis, result from this fixation, which paralyzes the person's free use of his own emotional and intellectual powers.

Third, Freud recognized that the conflict between father and son is characteristic of patriarchal cultures, and he demonstrated particularly how an unsuccessful rebellion against the father's authority and the fears resulting from the defeat form the basis for a neurotic development.

THE observation of these three phenomena led Freud to synthesize them in one brilliant theory. He assumed that the second phenomenon, attachment or fixation to the mother, was rooted in the first phenomenon—the sexual strivings of the child—and that the third phenomenon, the conflict with the father, was a result of this sexual rivalry. This theory is very appealing indeed. Individual and anthropological data gathered since Freud

formulated his theory have, however, shaken our conviction as to its validity. These data have shown that the Oedipus complex in Freud's sense is not a universal human phenomenon, and that the child's rivalry with the father does not occur in cultures without strong patriarchal authority. It has become evident that the tie to the mother is not essentially a sexual tie—in fact, that infantile sexuality when not suppressed has as its normal aim autoerotic satisfactions and sexual contact with other children Moreover, it has become apparent that pathological dependence on the mother is caused by nonsexual factors—particularly by a dominating attitude on the part of the mother, which makes the child helpless and frightened, thus intensifying the need for the mother's protection and affection.

The conflict between father and son—the aspect of the Oedipus complex with which we are here concerned—has little to do with sexual rivalry, but is characteristic of patriarchal society and family life In such societies the children, and particularly the sons, are conceived of as the property of the father whose interest they should serve. This concept is in opposition to fundamental qualities of human nature, to man's wish to be free and independent and to be an end and not a means. Hence an authoritarian, patriarchal structure necessarily results in a conflict between father and son, either overt or unconscious; rebellion against paternal authority results in a conflict of which the intensity is proportionate to the degree of pressure exercised by parental authority.

Freud's concept of the Oedipus complex is part of a broader concept in which neurosis is explained as the result of a conflict between the irrational passions of the child and reality represented by the parents and society. In such a concept it is the child who is the "sinner," and neurosis is the punishment, as it were.

The concept of the Oedipus complex presented here is also part of a larger concept of neurosis. The cause of neurosis is seen in the conflict, not between man's irrational passions and the justified demands of society, but between man's legitimate striving for freedom and independence and those social arrangements which thwart it, creating destructive passions which must in turn be suppressed by external or internal force.

Whereas Freud assumed that the conflict arising from the child's incestuous striving is rooted in his nature and is thus unavoidable, I believe that in a cultural situation in which respect for the individuality and integrity of every person—hence of every child—is realized, the Oedipus complex will belong to the past, as does the Oedipus myth.

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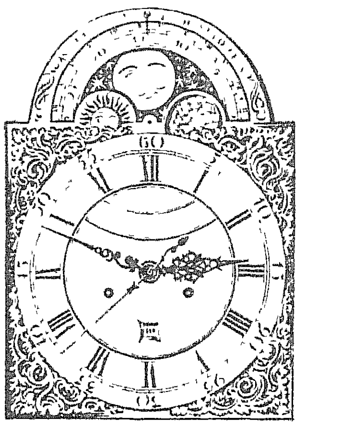
OEDIPUS DIES, and saves Athens, by entering the grove of the "Awful Goddesses." Fromm holds that the goddesses represented earlier matriarchal culture and that death of Oedipus was symbol of their victory in the play.



SCIENCE AND THE

Uranium Pile in France

THE first self-sustaining chain reaction to be produced outside of the English-speaking nations, which have hitherto possessed the "secret" of harnessing nuclear energy, has just been achieved by French physicists. Frederic Joliot-Curie, director of the French Atomic Energy Commission, announced that a uranium pile went into operation last month at Fort de Châtillon, on the outskirts of Paris.

The French pile has two unusual features: it uses heavy water instead of graphite as a moderator, and its reacting material is not pure uranium but uranium oxide. To U. S. workers, who have taken great pains to refine the uranium used in their reactors, the ability of the Châtillon pile to sustain itself on impure uranium is something of a surprise Joliot-Curie indicated that France hopes to trade this "secret" for "secrets" and uranium ore from other nations.

The French physicists developed their pile in a little less than three years at a cost of three billion francs—far less than the cost of the U. S and British piles. Joliot-Curie stated that the Châtillon pile is to be devoted not to military purposes but to the production of radioisotopes and to research on the harnessing of nuclear energy for heat and power.

Blackett Book

THE challenging and controversial work by the British physicist Patrick M. S. Blackett, *Military and Political Consequences of Atomic Energy*, which was recently published in England, will be brought out in the U. S. next month by Whittlesey House under the title *Fear, War and the Bomb*. A February selection of the Book Find Club, the book is certain to receive considerable attention among scientists and laymen in the U. S.

Blackett's volume, already widely discussed on both sides of the Atlantic, presents a detailed analysis of the atom bomb's impact on war and politics, and sharply criticizes the U. S. proposals for the international control of atomic energy. Its author, winner of the 1948 Nobel prize in physics, is a former member of the British Government's Advisory Committee on Atomic Energy and was a leader in wartime tactical research. The importance of his book was emphasized by the fact that the day after it was published in England, the British delegation to the UN Atomic Energy Commission issued a refutation of his views. The U.S.S R , on the other hand, warmly applauded them Recently the book was vigorously attacked by Frederick H. Osborn, U S delegate to the UN Atomic Energy Commission, in a radio debate with Blackett in England

Coldest Cold

THE lowest temperature ever attained in an American laboratory—.05 degrees above absolute zero—has been achieved at Ohio State University by a group under John G. Daunt.

Ohio State's "coldest cold" is somewhat short of the world record, .006 degrees absolute, achieved at the University of Leyden in the Kammerlingh Onnes Laboratory, the world's foremost center of low-temperature research. This record is not expected to stand for long, however. Three laboratories—Ohio State, Oxford and Leyden—are all at work on apparatus with which they expect to attain temperatures of one millionth of a degree absolute. Low-temperature research, now an active field in the study of the structure of matter, is also being conducted in other laboratories.

A.M.A. Campaign

AT least 55 million Americans pay part or all of their medical or hospital bills through a prepayment service plan or some form of insurance. The Blue Cross hospital plan, which is sponsored by the American Hospital Association, now furnishes hospital services to 32 million subscribers. In the field of medical care, on the other hand, coverage usually takes the form of privately written cash indemnity insurance The medical service plan sponsored by the medical profession, called Blue Shield, is not widely popular, for its geographical coverage is limited and the services it offers vary considerably.

Paul R. Hawley, former medical chief of the Veterans Administration and now chief executive officer of both Blue Cross and Blue Shield, proposed some months ago that the two organizations set up a national corporation empowered to offer uniform hospital and medical service throughout the country. He sought the support of the American Medical Association, arguing that the corporation was needed to head off compulsory Federal health insurance, now considered a distinct possibility as a result of the November election

Last month the A.M A House of Delegates refused to endorse Dr Hawley's plan and rebuked an A.M A agency, Associated Medical Care Plans, for taking part in preliminary organizing activities. The A M.A. objected to the plan on the ground that the national corporation might be in violation of the antitrust laws Dr. Hawley has announced that the corporation, which is to be known as the Blue Cross-Blue Shield Health Service, will go forward nevertheless.

The A.M.A. delegates, on the other hand, authorized a $25 assessment upon each of the A M.A 's 140,000 members to raise a $3,500,000 fund for an educational campaign on "the advantages of the American system in securing a wide distribution of a high quality of medical care" The manner in which the fund is to be spent has not been indicated. As a tax-exempt non-profit organization, the A.M.A. is not permitted to engage in activity on behalf of or against pending legislation.

School for Psychotherapy

A NEW type of school intended to relieve the great shortage of psychiatrists, of whom there are only 4,000 in the U. S., has been established in New York City by the non-profit Institute for Research in Psychotherapy. The school, called the Postgraduate Center for Psychotherapy, is training clinical teams of psychiatrists, psychologists and psychiatric social workers as staffs for new clinics. Some of its courses are also open to practitioners in allied fields, such as teachers, social scientists and ministers.

Agene Prohibited

WITHIN a year, nitrogen trichloride gas, better known under the trade name of Agene, will no longer be used for bleaching bread flour. It is off the new U. S. Food and Drug Administration list of approved wheat flour bleaches.

Nitrogen trichloride has been the most widely used bleaching agent for wheat flour for 25 years. In 1946 Sir Edward Mellanby, the English food chemist, discovered that Agene-treated wheat is a neurological poison which in dogs causes "running fits," a form of epilepsy. His finding was quickly confirmed in the U. S. and the substance was found toxic to several other mammalian species. No clear proof has yet been adduced as to whether Agenized flour is or is not toxic to human beings in the quantities present in the normal American diet. Army Quartermaster

Corps researchers hold that it may be responsible for the marked increase in ulcers in the U. S during the past generation. The physiologist Anton J. Carlson of the University of Chicago believes that it may be responsible for other neurological disorders as well.

About a year ago the baking industry began to switch to other chemicals for bleaching and curing the yellowish, hard-to-bake wheat meal that comes from the flour mill Completion of the compulsory changeover will take several months

Giant of South Africa

THE fossil remains of a new man-ape, one of the largest ever found, have been unearthed near Johannesburg, South Africa. The find was made jointly by a University of California expedition and Robert Broom, the discoverer of the man-apes Plesianthropus and Paranthropus (SCIENTIFIC AMERICAN, May, 1948)

The new fossil has been named Swartkrans Man. Broom's first report gives no indication of the age of the remains. They include a lower wisdom tooth, two upper incisors, an upper canine and a large part of a lower jaw with three premolars and four molars. The size of these teeth indicates that their possessors were heavier and possibly taller than Meganthropus of Java, a monster nine feet tall and two and a half times as massive as modern man.

Compared with the Swartkrans find, the other man-apes discovered in South Africa were pygmies. The three types in the family called the Australopithecines—Taungs Man or Australopithecus, Sterkfontein Man or Plesianthropus, and Kromdraai Man or Paranthropus—were only about four feet tall

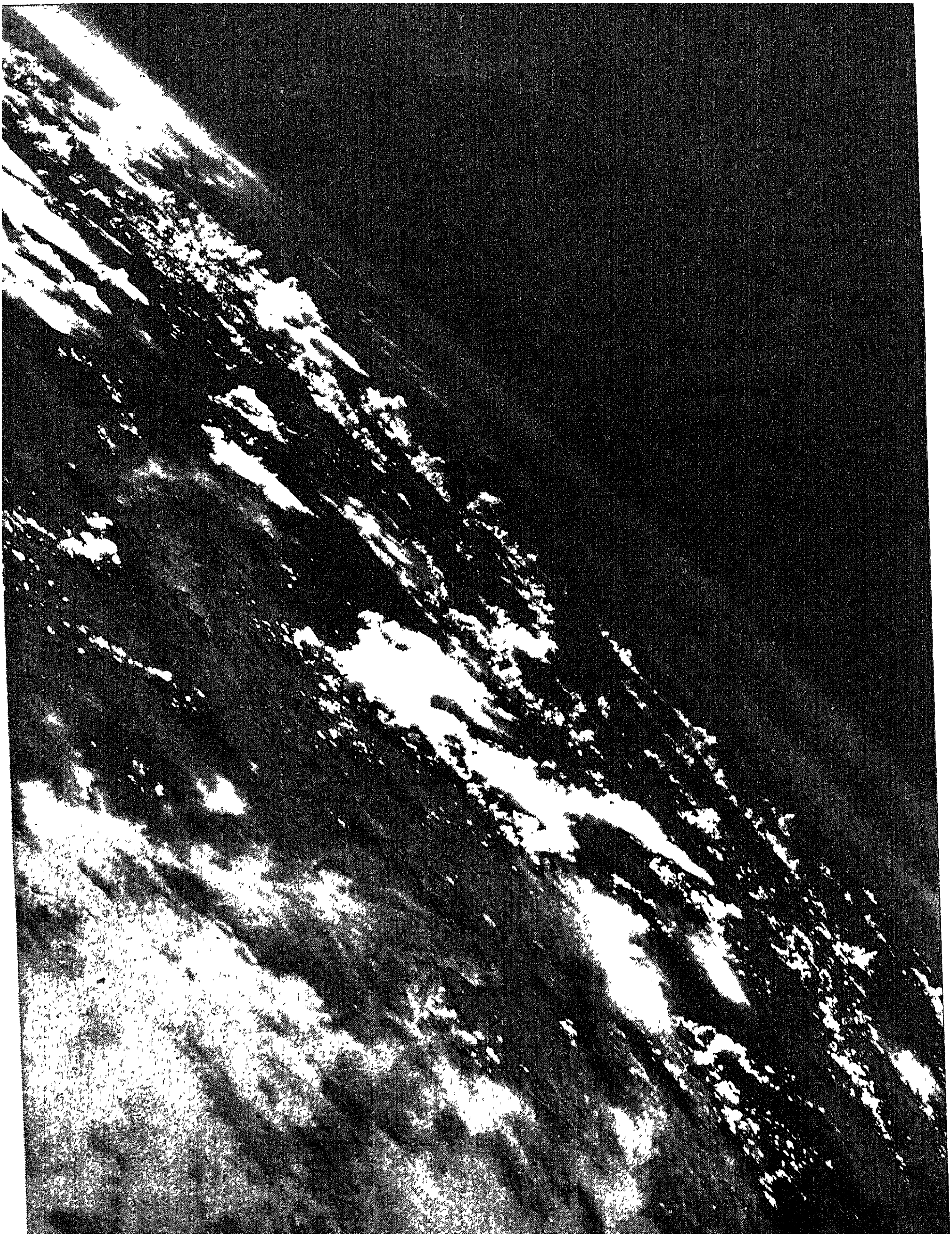
New UNESCO Director

JULIAN HUXLEY, the British biologist, has been succeeded as director-general of UNESCO by Jaime Torres Bodet, the 46-year-old foreign minister of Mexico Bodet, who will hold office for six years, was elected by a 30-to-3 vote. He is a teacher and poet who published his first works at the age of 16. Two years ago he won a world reputation for his brilliantly successful campaign against illiteracy in Mexico, built around the slogan "each one, teach one."

Meetings in February

AMERICAN PHYSICAL SOCIETY, Berkeley, California, February 3-5.

American Institute of Mining and Metallurgical Engineers. San Francisco, February 14-17.



THE TROPOSPHERE, the turbulent atmospheric layer at the earth's surface, is photographed from an Aerobee rocket 57 miles above White Sands, N. M. Below are the familiar cloud formations, which seldom extend above 7 miles. The hazy edge of the curved horizon illustrates the atmosphere's rapid thinning with altitude.

THE UPPER ATMOSPHERE

Above the thin layer of dense air in which we live is a great mantle of dispersed atoms and molecules swept by the ceaseless bombardments of outer space

by David I. Blumenstock

IN 1714 Edmund Halley of England, the foremost astronomer of his time, confidently observed: "The theory of the air seems now to be perfectly well understood, and its different densities at all altitudes, both by reason and experiment, are sufficiently defined." Halley's conception was simple. He calculated that the earth's atmosphere was 45 miles high, and that the air became steadily thinner and colder toward the top until it merged into outer space.

That, of course, was before radar, Geiger counters and V-2 rockets. We are now discovering that man lives on the floor of an ocean of air that is at least 2,000 miles deep and of subtle complexity. Its upper layers, which shield the earth against powerful bombardments from outer space, are swept by titanic tides of air and by radiations which raise their temperatures to fantastic levels.

For various reasons, largely military, the upper atmosphere is currently under most intensive investigation. Seldom has such a variety of scientific resources been brought to bear upon a single problem. Information about the upper atmosphere is being obtained from studies of meteors, comets, noctilucent clouds, auroras, the solar spectrum, radio waves, sound waves, the age of ancient rocks, the duration of twilight, the light of the night sky. Thus, although direct atmospheric measurements have been limited to some 20 miles by plane and balloon and to some 100 miles by rocket, the air seems now to be moderately well understood to a height of 500 miles.

Halley's calculations were based mainly on mountain climbers' soundings of air pressure and on Boyle's law, namely, that the volume of a gas varies inversely with the pressure to which it is subjected. Halley also cited as supporting evidence his observation that most meteors appeared at heights of about 45 miles; he accepted Aristotle's notion that meteors were formed from vapors that rose from the earth and condensed at the "top of the atmosphere." Halley's assumption that air pressure and temperature decreased uniformly with rising altitude seemed to be confirmed by later probings of the atmosphere by kite-flyers and balloonists, who by the early 19th century had reached heights of 20,000 feet and more. (Strangely, not until 1892 did it occur to anyone to send up an unmanned balloon equipped with instruments.)

The Three Shells

The modern understanding of the atmosphere began in 1898, when the French meteorologist Leon P. Teisserenc de Bort divided the air into two shells: 1) the troposphere (from the Greek, *tropos*, or turn), meaning the stirred-up lower portion, and 2) the stratosphere, the layered upper atmosphere. Twenty years later Arthur Edwin Kennelly of Harvard University and Oliver Heaviside of England, by studying reflected radio waves, proved the existence of the ionosphere, a region of ionized air particles above the stratosphere.

The troposphere, which is not really a sphere but an oblate spheroid, ranges in height from ten miles at the equator to five miles at the poles. This shell, closest to the earth, constitutes less than one third of one per cent of the total volume of the atmosphere, but its densely packed molecules account for more than 79 per cent of the total air mass. The stratosphere, extending from the top of the troposphere to a height of about 50 miles, represents less than two per cent of the atmosphere's volume and about 20 per cent of its mass. Above the stratosphere, the huge, rarefied shell of the ionosphere rises to 2,000 miles or more. Although it occupies more than 97 per cent of the atmospheric space, it accounts for less than half of one per cent of the air mass. Its gas particles, 10 million times rarer on the average than the air at the surface of the earth, are more widely spaced than in the best vacuum ever obtained with a laboratory pump.

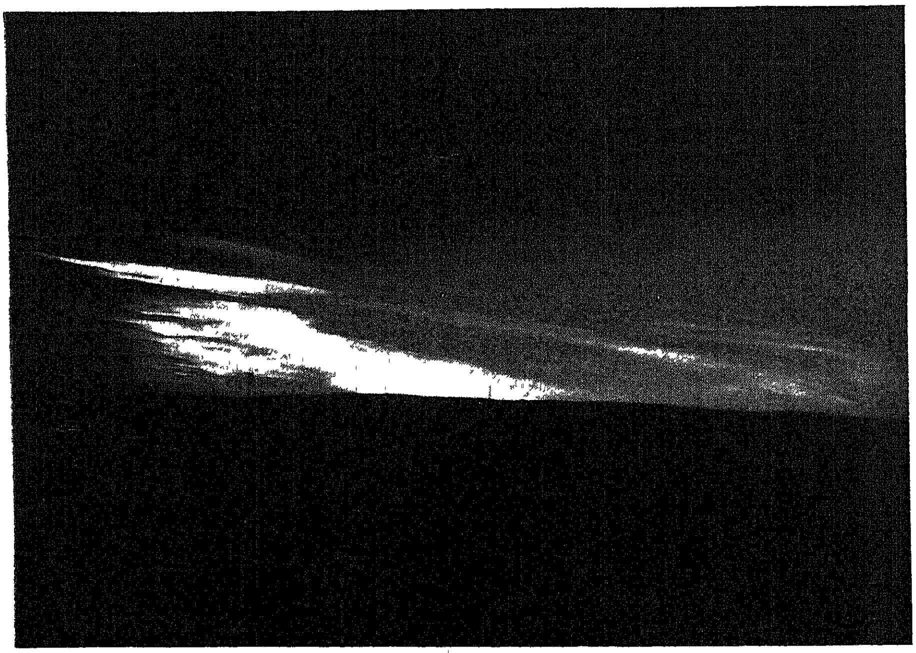
The principal interest of the present research is, of course, in the stratosphere and the ionosphere, which together are considered to constitute the upper atmosphere. It is convenient for discussion to divide the upper atmosphere into two regions: that below 500 miles, which is relatively well known, and that above 500 miles.

Gases in the Atmosphere

Of what is the atmosphere composed? Recent analyses have determined the troposphere's composition rather accurately. By volume, 99.99 per cent of dry tropospheric air is composed of just four gases, of which nitrogen constitutes 78.09 per cent, oxygen 20.95, argon .93, and carbon dioxide .03. The other one hundredth of one per cent is made up of neon, helium, krypton, hydrogen, xenon, radon and ozone (oxygen containing three atoms to the molecule). Because of the vigorous mixing of the air in the troposphere, the proportions of these various gases are remarkably uniform in samples of air taken everywhere on the earth.

There are, however, wide and important variations in other components of the air. Water vapor, for example, varies from four per cent by volume in the air overlying tropical oceans to .05 per cent or less at the top of the troposphere; the higher air is inevitably drier because rising water vapor is cooled and precipitated as rain, snow, sleet or hail. In addition to water,

NOCTILUCENT CLOUDS are a high, extremely rare formation that provides some information about the upper atmosphere. The altitude of noctilucent clouds is generally between 50 and 55 miles. This photograph was made near midnight from Drobak, Norway, by the astrophysicist Carl Störmer.



MOTHER-OF-PEARL CLOUDS, photographed from Oslo by Störmer, are seen at 13 to 18 miles. Because the temperature at this height is low, they are probably composed of ice crystals. Noctilucent clouds, however, are at heights where temperature is high. They may be made up of dust particles.

the lower atmosphere also has variable amounts of dust, bacteria, carbon particles and other material that is blown up from the earth's surface. Although these impurities form only an insignificant proportion of the air by weight or volume, they have a most important effect on the weather, for they provide nuclei for the condensation of water. They may also drift into the upper atmosphere and help to form the high stratospheric clouds there.

Far different is the composition of the upper atmosphere. Its principal ingredients are still nitrogen and oxygen, but there are significant changes in the lesser gases Two excellent illustrations are radon and ozone. Radon, a product of the decomposition of radium, originates from radioactive rocks on the earth. As the heaviest of the atmospheric gases, seven times as heavy as dry air, it tends to settle at the bottom of the atmosphere, moreover it is radioactive, and so is apt to disintegrate before it can be blown up to high levels. Hence radon has never been found in the upper atmosphere.

Ozone, on the other hand, originates in the upper atmosphere; it is created in the lower stratosphere by the action of the sun's ultraviolet light on molecular oxygen. As it descends into the troposphere, it becomes dissociated again into ordinary molecular oxygen Ozone, therefore, is relatively rare at ground level, but increases with higher altitude

The distribution of ozone in the air has been measured with considerable accuracy by methods involving the absorption of light by the gas. These methods are based on the principle that ozone absorbs some wavelengths of light strongly and others weakly. If light that includes both kinds of wavelengths passes through a thin layer of ozone, a wavelength that is only weakly absorbed will come through with much less impairment than one strongly absorbed. If such light goes through a thick layer of ozone, the absorption of the two wavelengths will be more nearly equal—just as thick armor plate stops a high-speed bullet as well as a low-speed one. By measuring the differences in absorption by ozone of such pairs of wavelengths, the amount of ozone in the air can be determined. One method uses the light from the sky overhead toward sunset. This light reaches the earth by a dog-leg route from the setting sun: the sun's light follows a long, slightly curved path to the sky over the observer, then zigzags downward to the earth through the atmosphere. As the sun sinks lower and lower toward the horizon, the region from which most of the overhead light comes is at higher and higher levels. Thus the first section of the dog-leg route rises and provides a moving yardstick for measuring ozone absorption at successive levels.

These measurements have established that there are appreciable amounts of ozone in the air at altitudes of from one

to 30 miles, 60 per cent of it is concentrated in the region from 10 to 20 miles. If all the ozone in the atmosphere were concentrated in one pure layer at sea-level pressure, it would form a film over the earth only about one tenth of an inch thick. Yet this small amount plays a large role. As a powerful absorber of solar radiation, ozone heats the stratosphere to much higher temperatures than those in the troposphere. The fact that the ozone content of the troposphere varies with surface air pressure may prove helpful in weather forecasting. It may also be significant that the ozone layer is thicker and lower at the poles than at the equator and that the ozone content of the air is greatest in spring and least in autumn.

As for other gases, it appears unlikely that the upper atmosphere contains any xenon or krypton, both of which are considerably heavier than air; it can have only traces of carbon dioxide, argon and neon, all of which are extremely rare even at sea level.

Helium

The principal unanswered question is: How much helium exists in the upper air? The great height of the atmosphere argues that its upper levels are filled with some very light or hot gas. Does helium become more and more common at high levels?

This question has been studied by spectroscopic analysis of the absorption and emission of light by the various gases in the atmosphere. Each gas, of course, provides a fingerprint of itself by its characteristic absorption of light at certain wavelengths. Examination of the absorption spectra of the upper air shows no evidence of helium. This is not conclusive, however, for other known constituents of the air, notably nitrogen, also fail to produce absorption spectra, either because they do not absorb strongly at the temperatures that exist in the upper atmosphere, or because they absorb at short ultraviolet wavelengths where they are masked by the broad absorption bands of ozone in the same region.

Emission spectra—the identifying radiations emitted by each gas when its molecules or atoms are excited—have yielded more significant information. They are obtained from auroras and from the faint light given off by the night sky. The auroras are produced by the excitation of the upper air by corpuscles emitted from the sun. Because the corpuscles are charged, they are swerved by the earth's magnetic field and swarm toward the two magnetic poles. Thus the auroras are usually seen at far northern or southern latitudes. By means of simultaneous photographs from two or more places, the auroral displays can be located in space, and they have been found to extend up to 400 miles above the earth. Although their spectra show abundant evidence of nitrogen and oxygen in the upper atmosphere, they exhibit no sign of helium. The night sky spectrum (which, incidentally, shows the emission line of atomic sodium, the presence of which in the upper atmosphere has not been explained) also fails to show helium.

These observations do not rule out the presence of helium, for it is still unknown whether the electromagnetic field in the auroral regions is strong enough to excite helium atoms so that they emit light. Nevertheless the weight of the evidence indicates that the upper atmosphere, at least up to a height of 500 miles, consists predominantly of oxygen and nitrogen at high temperatures, a condition which would account for the height of the atmosphere as well as would helium.

If this is the case, what has become of the vast quantity of helium that has been fed into the atmosphere by the breakdown of radioactive elements in rocks during the millions of years of geological time? It has been calculated that during its lifetime the earth's crust has released more than 12 times as much helium as now exists in the atmosphere, even assuming that the ionosphere above 500 miles is nothing but pure helium. The only possible explanation is that helium is constantly escaping from the outer atmosphere into interplanetary space. The velocity of helium atoms even at moderate temperatures is great enough so that at heights of many thousands of miles huge numbers of helium atoms could escape from the earth's gravitational field.

The same holds true for hydrogen. In the lower atmosphere only the barest traces of this gas exist—a mere .00005 of one per cent by volume, according to measurements by the British chemist F. A. Paneth. If helium escapes from the atmosphere, hydrogen must do so at a very much faster rate, for the hydrogen molecule is lighter and speedier than the helium atom. It is most unlikely, therefore, that the upper atmosphere contains any appreciable amount of hydrogen. This conclusion is supported by certain laboratory experiments in which auroral spectra have been reproduced. It was found that even a trace of hydrogen suppresses the afterglow that is characteristic of auroral emission.

Clouds

Nearly all of the clouds in the sky, even the high, wispy cirrus clouds and the towering thunderclouds, lie wholly within the troposphere. But there are two kinds of clouds that do belong to the upper atmosphere. One is the mother-of-pearl clouds, so called because of their shiny, banded coloring. They have been observed in northern latitudes, notably over Norway, at stratospheric levels of 13 to 18 miles. Because temperatures at these heights are very low, the cloud particles probably are ice or supercooled water droplets. These clouds may be formed by a welling up of tropospheric air that thrusts small amounts of moisture into the stratosphere.

The other type is the noctilucent clouds that sometimes appear at the top of the stratosphere after sunset, shining in the western sky from the reflected light of the sun. These clouds may be composed of dust particles rather than water, because the temperatures at the top of the stratosphere seem to be too high to permit the existence of water or ice molecules at the low pressures prevailing there.

From all this wide variety of evidence, the upper atmosphere is deduced to be made up almost entirely of nitrogen and oxygen, with some ozone, small amounts of helium, and traces of nitrogen pentoxide, neon and atomic sodium. Above 100 miles, as the result of dissociation by ultraviolet light, all of the oxygen and at least part of the nitrogen exist in the atomic rather than the molecular form. And the evidence of spectrographs and the reflection of radio waves shows that, at least in the lower ionosphere, the oxygen and nitrogen particles are largely ionized.

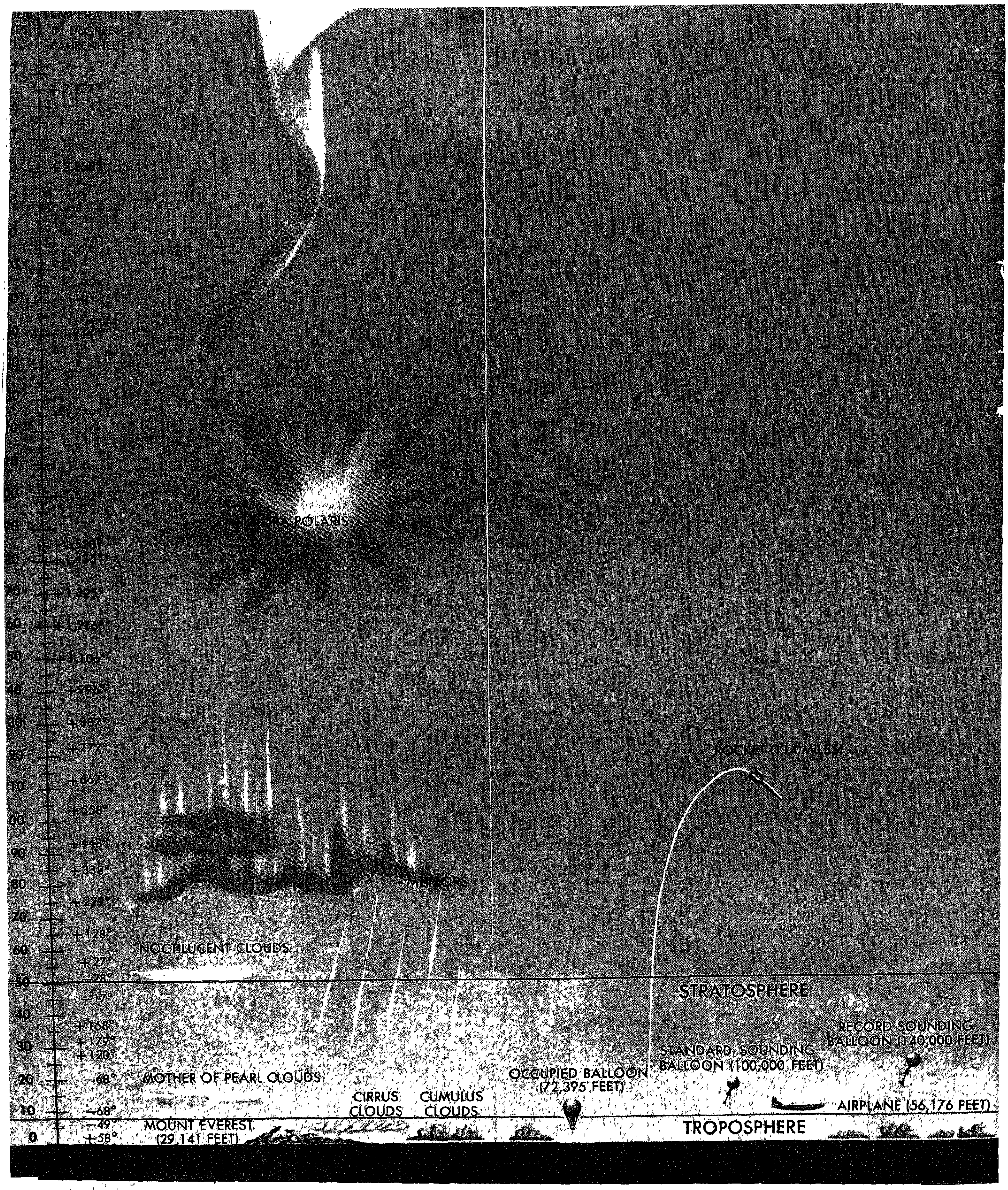
Temperature and Density

Thirty years ago the prevailing conception of the temperature and density of the atmosphere was still much like that constructed by Halley. It was generally thought that temperature dropped steadily through the troposphere, remained about constant through the stratosphere, and then decreased nearly to absolute zero in the outer reaches of the atmosphere. There were one or two puzzling contradictions that did not fit into this simple picture. A cold atmosphere is a shallow atmosphere, and it is therefore extremely rare at great heights. It seemed strange that such a rare upper atmosphere would provide enough air particles to produce auroras to heights of 400 miles and to form strongly marked ionized layers at heights of 100 miles and more. But too little was then known about auroras and ionized layers to challenge the prevailing theory.

Thirty years of research since then have entirely changed our understanding of the atmospheric profile. It is now fairly well established that the upper atmosphere ranges from warm to hot, with at least two zones of extreme rises in temperature and two of precipitate drops. The pioneering studies that had most to do with forming this picture were those on the peculiar irregularities in the propagation of sound, and those on the behavior of meteors.

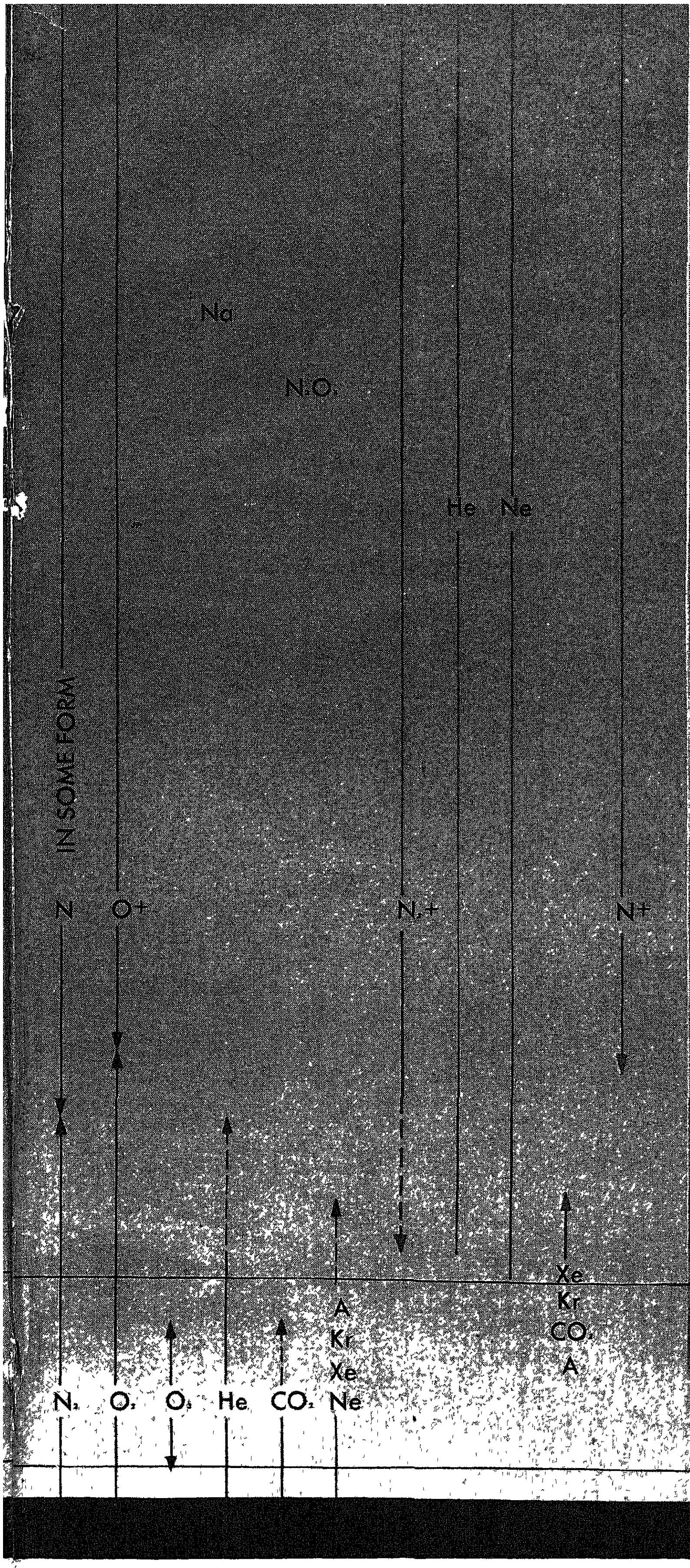
Skipping Sounds

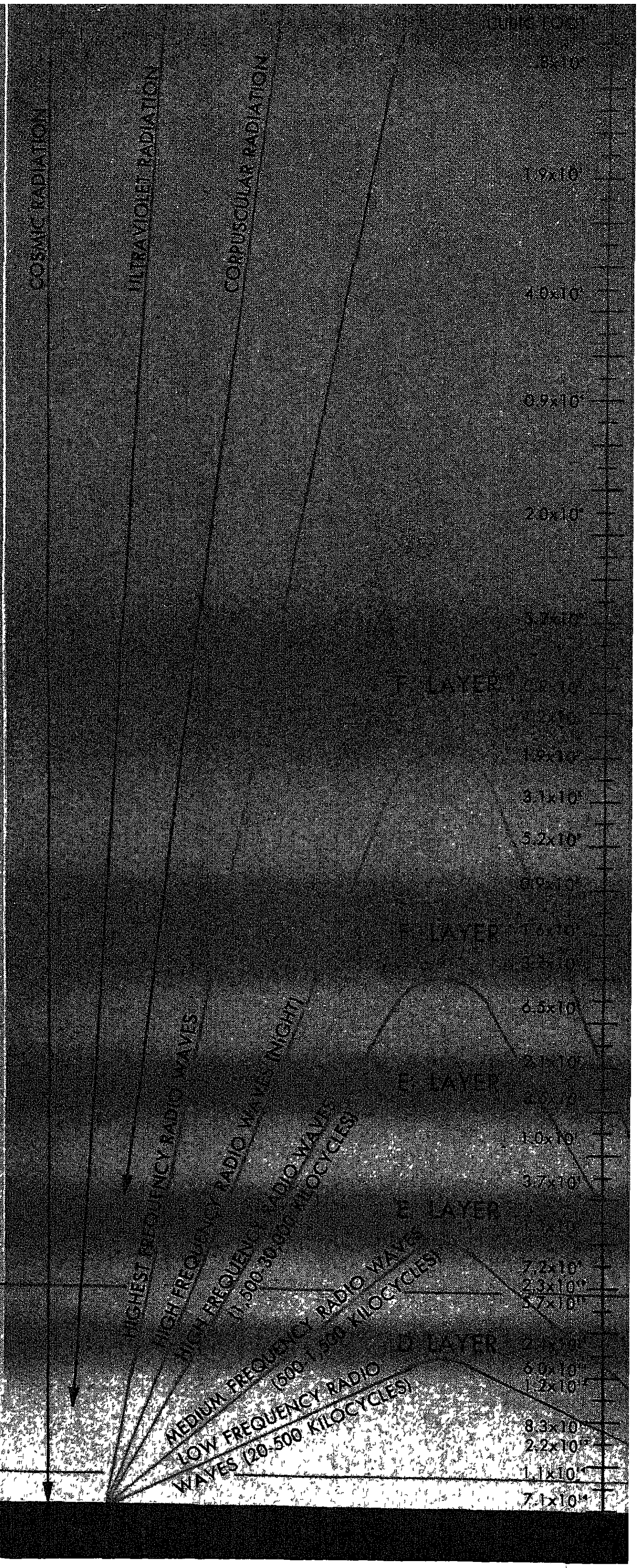
During World War I it was often noticed that the sounds of explosions seemed to travel in hops. A specific explosion might be heard at 30 miles and at 60 miles from the point of detonation, but not in the areas between. When the areas of audibility for a given explosion were plotted



PRINCIPAL FEATURES of the lower part of the upper atmosphere are shown in four profiles on these two pages. Given above are the altitudes of clouds, the heights at which meteors appear (50-80 miles) and disappear (10-50 miles). Aurora levels are 60-400 miles.

LITERAL EXPLORATION of the atmosphere has thus far been limited to a few low-altitude excursions. Rockets have penetrated the ozone layer (*see third profile from left*) to reveal important information about the ultraviolet radiation entering the upper atmosphere.

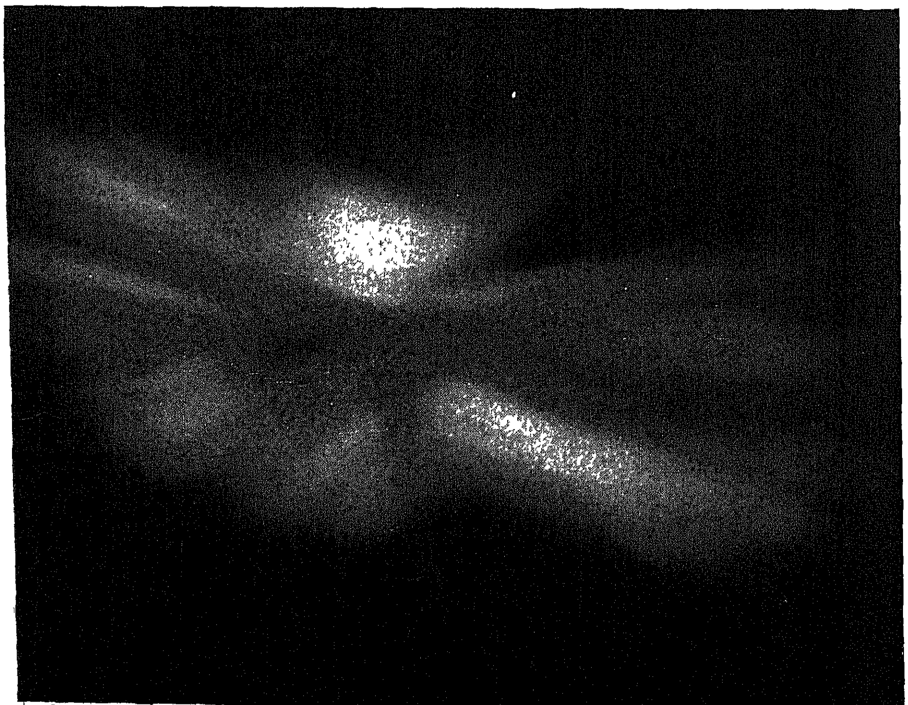




DISTRIBUTION OF GASES according to altitude shows much variation when entire atmosphere is considered. Heavier gases tend to concentrate at lower levels. Ozone layer is indicated by O_3. Accepted information is indicated by black arrows; tentative data in red.

THE IONOSPHERE is a vast shell of gas atoms and molecules ionized by radiations bombarding the earth from space. These charged atoms and molecules reflect radio waves. Longer waves are most easily reflected; higher frequencies tend to penetrate ionospheric layers.

AURORA POLARIS is caused when a great stream of charged particles emitted by the sun enters the upper atmosphere of the earth. The atoms and molecules of gas in the atmosphere are thus excited to emit light.



AURORAL RAYS are the result of the earth's magnetic field. When charged particles from the sun enter the upper atmosphere, the magnetic field swerves and channels them to form the characteristic auroral patterns.

on a map, they formed a banded pattern in the shape of a set of concentric rings; rings or zones of audibility alternated with zones in which the sound was not heard at all. Clearly the sound waves were moving outward from the source in looping jumps, like a stone skipping across a pond

The obvious explanation was that the sound waves were bouncing back and forth between the earth and the roof formed by the upper atmosphere. But how could the cold upper air bend the waves back toward the earth? It was known that the velocity of sound decreased with decreasing temperature of the air. If the air became steadily colder as a sound wave rose diagonally from the ground, then the upper part of the sound-wave front, being in colder air, should travel more slowly than the lower part, and the wave would pivot and be bent upward, not downward.

There were two possible ways of accounting for a sound wave's being bent downward. One was to assume that the wave encountered a layer containing a very light gas such as hydrogen or helium. Since the velocity of sound increases with the decreasing molecular weight of air, the lighter gas on the upper side of the wave would serve to speed up that part and pivot the wave downward. To produce the amount of downward bending that was observed, however, hydrogen or helium would have to constitute at least 25 per cent of the stratospheric air. All the evidence denied such an assumption; for one thing, if there were so much hydrogen or helium in the stratosphere, there would be a much higher percentage of those gases in the lower atmosphere than had ever been observed. Meteorologists were therefore compelled to accept the other explanation: that the waves were bent downward by regions of high temperature in the stratosphere.

As a sound wave rises from its source it is first turned upward by the increasingly cold air of the troposphere. This accounts for the first skip, *i.e.*, the zone on the ground in which the sound cannot be heard. When the wave reaches the warmer air of the stratosphere, it is turned back, and thereafter it bounces between the ground and the stratosphere over a widening region until its energy is reduced to inaudibility.

Calculations based on the bounces of the sound waves placed the reflecting, high-temperature region in the stratosphere at a height of roughly 25 to 40 miles. The next step was to define the region and compute its temperatures by means of more precise experiments. One of the most successful experiments, conducted by F. J. W. Whipple in England, used an extremely sensitive special microphone to detect the reflections of sound waves, to define the zones where they were received on the ground and to determine their angle of arrival. Whipple's careful experiments and those of other investi-

gators showed that in the upper stratosphere temperatures rise with increasing altitude from 15 to 30 miles and reach 150 degrees F at the 30-mile level.

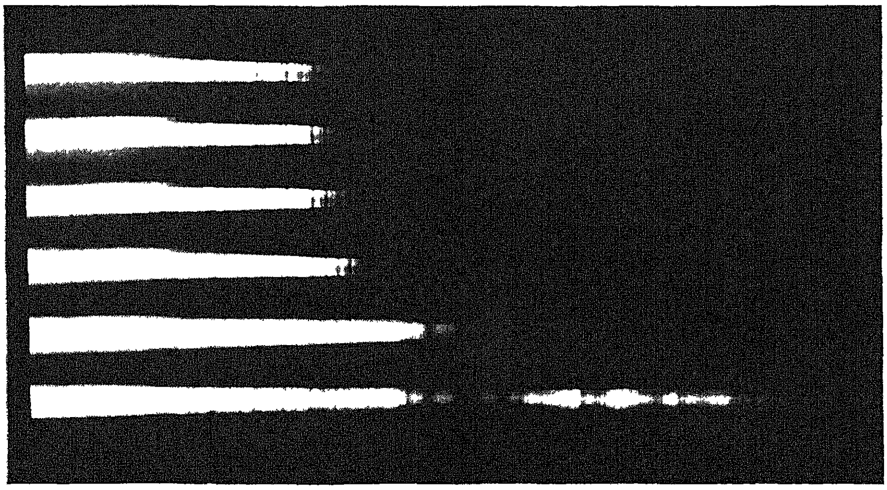
Meteor Tracks

Approximately the same findings had been made even earlier as the result of studies of meteors by F A Lindemann and G. M B. Dobson of Oxford University. They reasoned that upper atmosphere densities must be related to the behavior of these tiny objects, most of them no bigger than a pinhead, which appear suddenly in the lower ionosphere and produce a long, bright trail across the sky.

The minuscule meteor itself is invisible Whizzing through the atmosphere at tremendous speeds, up to 60 miles a second or more, it leaves a cone-shaped train of incandescent vapor which may remain luminous for many minutes. Ordinary air could not retain an incandescent temperature for any such length of time It is likely that the meteor ionizes and dissociates the air molecules, creating energized particles which continue to radiate long after the meteor itself has disintegrated.

Meteors usually are first seen at from 50 to 80 miles above the earth and disappear in the region between 10 and 50 miles. Where do they come from? Why are they visible only in this specific portion of the atmosphere? And how can such tiny objects travel scores of miles before vaporizing? Lindemann and Dobson reasoned that the meteors shoot into the atmosphere from interplanetary and interstellar space at such enormous speeds that the relatively few air particles they strike in the thin outer atmosphere radiate their tremendous energy almost instantaneously, and so do not have time to pass on that energy to other particles to form a luminous trail. As the meteor descends into denser air, more and more air particles pile up in front of it. They form a cap of compressed air ahead of the meteor Not until this cap is heated to a high temperature and passes its heat to the meteor itself does the meteor begin to vaporize This is the stage at which the meteor makes its appearance, what the observer sees is the incandescent air cap and the trail of hot vapor

If this theory is correct, when the speed and height of a meteor are known one can estimate the density of the air at the levels at which the meteor appears and disappears. On the basis of observations of several hundred meteors, Lindemann and Dobson estimated that the atmosphere from 40 to 100 miles up must be more than 1,000 times denser than was previously supposed, and that the temperature in this region must be at least 80 degrees F Their estimate was confirmed by several kinds of independent evidence, including the fact that at the lowest speed at which meteors have been observed (12 miles per second), the temperature of the air must be at least 80 degrees to vaporize them. Curiously, Lindemann and Dobson found that there was a certain zone, from 30 to 35 miles above the earth, in which very few meteors disappear. This may be explained by assuming that at about this height the meteors encounter colder air and so are less likely to burn out.



SPECTRA OF SUN made from V-2 rocket graphically demonstrate ultraviolet cut off by ozone layer. Spectra, from top, were made at heights of 1, 4, 10, 15, 20 and 35 miles. Short ultraviolet wavelengths are to the right.

The Lindemann-Dobson theory has been challenged, but both their theory and their conclusions have stood up remarkably well since they were first propounded more than 25 years ago. Moreover, many other lines of research, besides those on meteors and sound waves, have supported their concept—research that has to do with the tides in the atmosphere (which, like the oceans, is subject to the pull of sun and moon), with the duration of twilight, with reflection of radio waves, and with the spectra of the night sky and auroras.

The Profile

It is now possible to construct temperature and density profiles of the atmosphere that are highly accurate to a height of at least 20 miles and founded on much reliable evidence for the higher regions (*see chart on pages 34 and 35*). In the middle latitudes of the Northern Hemisphere, the temperature falls from a mean of 50 degrees F. at ground level to 55 degrees below zero at the top of the troposphere; stays at that level in the lower stratosphere to 20 miles, rises in the region between 20 and 30 miles; drops back to 28 degrees below zero at the top of the stratosphere (50 miles); and then, as the result of ionization in the lower ionosphere, rises to a scorching 2,800 degrees in the 300-to-500-mile zone.

Most of the investigations of the atmosphere have been made in the middle northern latitudes, and therefore relatively little is known about the higher air over the Southern Hemisphere and the equatorial region. There must be distinct differences in the profile from latitude to latitude because of the varying height of the troposphere, differences in the intensity of sunlight, variations in ozone content, the influence of the great southern oceans and of the very cold Antarctic continent, and so on

Paradoxically, in the troposphere the lowest temperatures occur not over the poles but above the equator, where the temperature at the top of the lower atmosphere averages 100 degrees below zero The chief reason for this is that the vertical air currents at the equator ascend to great heights so the air cools greatly by expansion; near the poles the air movement is mainly downward and the air is warmed by compression. Another reason is that ozone, which is strongly heated by ultraviolet rays from the sun, is more abundant over the poles than over the equator.

The Ionosphere

The most fascinating of all the regions in the upper atmosphere is the turbulent, highly charged ionosphere. The ionosphere is the earth's frontier with outer space. Upon this buffer region falls an immense electromagnetic cannonade: light rays, ultraviolet and infrared radiations, radio waves and corpuscular streams from the sun, similar radiations from other stars, cosmic rays from interstellar space beyond the solar system. All these impacts produce a great variety of effects on the molecules and atoms of the upper air. The ultraviolet radiations, for example, knock electrons from the air particles, split molecules into atoms and leave ionized molecules and atoms. Cosmic rays, shooting into the nuclei of air atoms at huge energies, produce a vast, energetic debris which cascades down through the atmosphere, creating powerful secondary showers.

Approaching the earth, all these incoming radiations encounter not only an increasingly dense mass of air molecules, but the earth's magnetic field. The charged

radiations from outer space and the ionized particles they produce are strongly deflected by the terrestrial magnet. Indeed, it was through the observation of changes in the earth's magnetic field that the charged layers in the ionosphere were first discovered. The British researchers Balfour Stewart and Arthur Shuster noticed that the magnetic field showed daily variations in intensity that could not be explained by changes in the earth itself. They concluded that these variations must be caused by electrical currents in the upper air, and that the daily cycle was due to day and night differences in the number and distribution of ionized particles in the charged atmospheric layers.

This conclusion was confirmed by the later studies of radio waves. There are distinct differences in the reflection of radio waves from the upper atmosphere by day and by night. Radio waves, as is now known, are reflected from the ionosphere in a manner analogous to the reflection of sound waves from the stratosphere. When a radio wave enters the ionosphere, it induces a current among the charged air particles there. The upper part of the wave front, being in a more highly charged area, is speeded up; thus the wave pivots and is bent downward. The resulting bounces of the radio wave between the ionosphere and the ground account for the reception of radio signals around the curvature of the earth. Because the amount of current induced among the ionized particles depends on the wavelength of the radio impulse, there are variations in the bending of such waves; very short radio waves normally are not reflected back to the earth and hence they cannot be transmitted beyond the horizon.

Measurements of the height and amount of bending in radio waves of various frequencies make it possible to determine the height of the charged layers in the ionosphere and to estimate their thickness. These measurements also indicate the density of free electrons, and therefore the temperature, at various levels.

The Layers

The calculations show that there are two principal reflecting layers: the so-called E layer at 60 to 70 miles and the much thicker F layer (actually composed of two separate layers known as F_1 and F_2) at 120 to 200 miles. Two lesser layers have also been identified: an intermittent D layer at 35 to 40 miles and a high G layer somewhere above F. None of the four layers is sharply defined; each simply represents a region of maximum ionization. It is thought that the E layer may be produced by the ionization of molecular oxygen, the F_1 layer by ionization of molecular nitrogen, and the F_2 layer by ionization of atomic oxygen.

Because the energy for ionization comes largely from ultraviolet radiation, the height and thickness of the layers vary with the daily, seasonal and long-term solar radiation cycles. The E and F_1 layers are most sharply defined at the times and places of maximum solar radiation; *i.e.*, within the tropics, particularly at noon, and at noon of the summer solstice outside the tropics. Ionization of these layers also increases in periods of sun-spot activity.

The F_2 layer seems to be a special case; during the summer it has a double daily maximum, morning and afternoon, and its seasonal peaks occur at the equinoxes. There are marked fluctuations in the strength of this layer from day to day. Apparently it is strongly affected by magnetic storms. These storms, which spasmodically sweep the upper atmosphere, are caused chiefly by solar eruptions that produce sudden bursts of intense ultraviolet radiation, radio waves, or corpuscular streams. These electromagnetic upheavals obviously have a powerful, sometimes completely disruptive, effect upon radio communications on the earth.

There is evidence that the upper atmosphere is also stirred by gales far more violent than any in the troposphere. In the lower stratosphere, free balloons tracked by radio have shown wind velocities approaching 200 miles per hour, and the motion of noctilucent clouds at the top of the stratosphere indicates 400-m.p.h. winds there. The middle stratosphere is quieter; observation of the wind-tossed tracks of meteors in that region shows that the winds, predominantly easterly, range from 65 to 170 m.p.h. The winds of the lower stratosphere in high northern latitudes are generally westerly in winter, easterly in summer. Little is known about the winds of the ionosphere, but the extremely wide daily temperature ranges produced there by solar ionization must result in vigorous vertical air currents.

The Outer Regions

The atmosphere above 500 miles is still an unplumbed mystery. Beyond 500 miles there are no auroral lights, reflecting layers or other clues to help the investigator. But physical reasoning and theory and astronomical observations offer some guidance.

It is known that this outer atmosphere must be extremely rarefied; by the most conservative estimate it is less than one billionth of the total atmospheric mass. Any estimate of the height to which it extends depends in part on the definition of the atmosphere. One approach is to define the top of the atmosphere as an equilibrium surface analogous to that of a liquid in a closed container. The net loss of molecules from such a liquid is zero, because the number of molecules evaporating from the liquid into the overlying saturated air is exactly balanced by the number returning to the liquid from the air. By analogy, it is possible to picture the top of the atmosphere as a surface at which the escaping air particles are balanced by incoming particles of interstellar gas.

Sir James Jeans, Lyman Spitzer and other astronomers have estimated that the temperature of the interstellar gas is from 18,000 to 27,000 degrees F. Assuming that the temperature of the atmosphere increased from the F layer upward at a rate inversely proportional to the square of the height, that the air particles at the top of the atmosphere were at a temperature of 18,000 degrees, and that they consisted, like the interstellar gas, almost wholly of ionized atomic hydrogen and free electrons, G. Grimminger of the Douglas Aircraft Company has calculated that the height of the atmosphere would be about 16,000 miles. If the outer atmosphere is assumed to consist of atomic nitrogen, similar calculations would give it a height of about 6,500 miles. Computations based on other gases give height values between 6,500 and 16,000.

An outer atmosphere of hydrogen, as has been pointed out, seems highly unlikely, for at a temperature of 18,000 degrees the speedy hydrogen atoms would zip off into space. Atomic nitrogen or atomic oxygen, however, would be held by the earth's gravitational field at heights of 16,000 miles and beyond. Still, the evaporation analogy or equilibrium approach is not entirely satisfactory as a means of calculating the height of the atmosphere, for it ignores the likelihood of dissipation of the outermost atmosphere through the escape of exceptionally speedy individual particles. The atmosphere is so rare above 500 miles that particles often travel hundreds or thousands of miles before being checked by collision with other particles. Thus the chances are high that individual particles may curve off into outer space without interference. The calculations of maximum height of the atmosphere are based on average particle velocities, but if it is assumed that the velocities of individual particles are not uniform—the usual condition in gases—some of the particles might be above the critical escape velocity. Because of their escape, the height of the atmosphere would be less than calculated.

A better approach to this problem has been suggested by the British cosmologists E. Arthur Milne and Sir James Jeans. They reasoned that at great heights a critical level must be reached where the frequency of collisions between particles is so low that for all practical purposes it is zero. At this level and above, the particles would move as free bodies in a gravitational field. Those starting upward would be unchecked and would leave the atmosphere whenever their velocity was greater than the escape velocity. The velocity of a particle would depend on its composition and temperature. If these

two factors were known—or assumed—the nature and height of the atmosphere above the critical level could be computed on a basis of statistical probability.

Following this line of reasoning, Grimminger has constructed a model for an upper atmosphere composed of atomic nitrogen and atomic oxygen. He placed the critical level arbitrarily at the stage where the mean collision frequency is one collision per particle each 20 minutes. Starting with the known temperature in the F_2 region at about 180 miles (computed from radio-reflection measurements), and assuming that the temperature increases at a rate inversely proportional to the square of the radial height, he calculated that the critical collision level is reached at a height of 391 miles at the 45 degree northern latitude. Above this level the temperature stabilizes at 2,839 degrees F. and the particle density decreases at such a rate that at 5,500 miles there are only two particles per cubic mile.

Temperature has a different significance in the rare upper atmosphere than at sea level A space ship in the hot upper atmosphere would not be warmed by the air; there would be too few air particles striking the ship to speed up the molecules in its hull. The ship could gain or lose heat only by radiation. "Temperature" in the ionosphere is simply a measure of the speed of the particles of which it is composed.

Grimminger's calculations are admittedly approximate and involve a number of simplifications (for example, they do not allow for the intrusion of interstellar gas particles in the uppermost atmosphere). Above the 1,000-mile height, his estimates are at best a guess But for the regions between 500 and 1,000 miles his results are probably of the right order of magnitude, if his assumption of an atmosphere of atomic nitrogen and oxygen is correct. Grimminger's analysis was made for the purpose of assisting in the design of rockets to be shot to the 500-to-1,000-mile levels

The immense outer atmosphere offers an immense and exciting area for exploration. Is the upper atmosphere constantly invaded by great quantities of interstellar gas—a possibility suggested by the fact that sodium ions, which are known to be present in such gas, have been detected in the night sky spectrum? What effects do the turbulences of the upper atmosphere produce on the weather of the troposphere in which we live? These and scores of other problems are being investigated. From rocket flights and from the kinds of indirect evidence by which we have derived our present knowledge, we shall certainly learn a great deal more about the upper atmosphere in the next few years.

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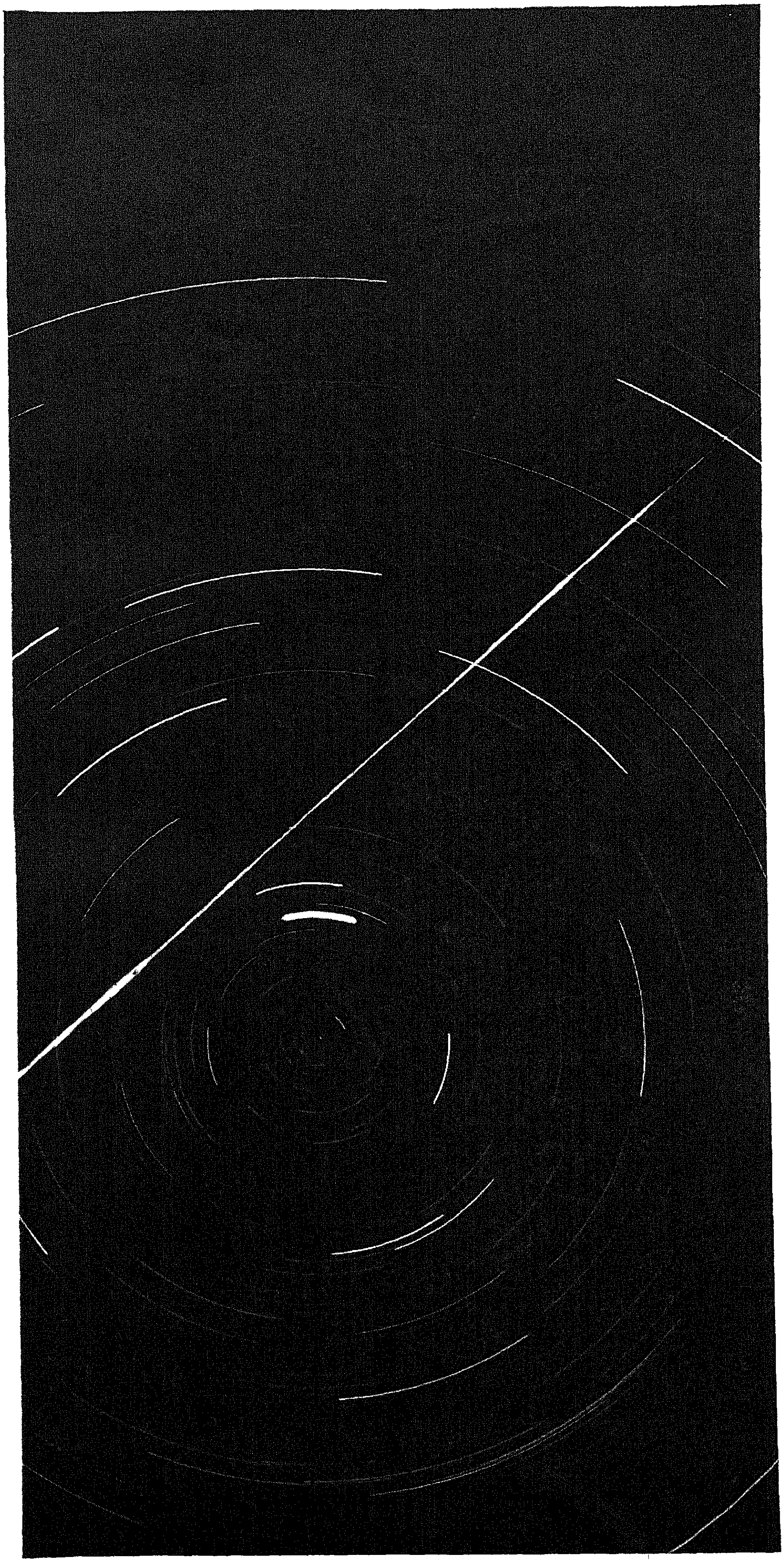


TRAIL OF A METEOR yields information about the upper atmosphere because it is largely made up of incandescent atmospheric gases. Camera is pointed toward the pole star. Stars left curved paths during time exposure.

ORNATE DECORATION appears on the first page of Pierre de Fermat's *Introduction to plane and solid loci*. This presents Fermat's independently developed principles of analytic geometry.

THE INVENTION OF ANALYTIC GEOMETRY

It is generally attributed to the great Descartes, but its development goes back as far as attempts to solve the famous riddle of the oracle at Delos

by Carl B. Boyer

ANALYTIC geometry is usually defined as the combination of algebra and geometry through the method of analysis, and its invention is credited to the great 17th-century French philosopher René Descartes. Both these notions, as it happens, are historically inadequate. The term analytic geometry is perhaps as difficult to define as is the word mathematics, and the origin of the one is not more easily indicated than that of the other. The story of the evolution of analytic geometry, indeed, is the history not of a single discovery but of a famous problem and its slow solution, of the essential unity of mathematics and of the growth of mathematical ideas.

The realms of arithmetic and geometry have of course never been entirely independent. The very idea of the measurement of lengths, areas and volumes implies the application of number to geometrical configuration, and this general concept may be taken as the source from which analytic geometry arose. The Babylonians of some 4,000 years ago measured the sizes of rectangular figures with great accuracy, and they made a start on the geometry of the circle. They were well aware of the fact that the sum of the squares of the legs of a right triangle is equal to the square of the hypotenuse—which history has misnamed the Pythagorean theorem. They also took the initial steps toward the idea of a coordinate system. Coordinates are simply magnitudes or distances that determine the position of one point or object with respect to certain other fixed points, lines or objects. Babylonian astronomers, for example, determined the position of a planet at a given time by specifying its angular distances from certain fixed stars or stellar configurations. Egyptian surveyors similarly located points in the Nile Valley by means of a coordinate frame not unlike that formed by a network of city streets and avenues.

Inasmuch as analytic geometry is known also as coordinate geometry, one might be tempted to assume that its invention was a direct consequence of such pre-Hellenic astronomy and geography. This, however, was not the case. Analytic geometry did not arise out of practical problems; it was instead the outgrowth of questions of a purely theoretical and speculative nature.

The source from which the invention arose was one of the classical problems of the age of Pericles. The story goes that Athens was afflicted by a plague, and its citizens, upon appealing to the oracle of Apollo at Delos, were instructed to double the size of the cubical altar. It was generally understood that the cube was to be doubled or "duplicated" exactly, using only compasses and an unmarked straightedge. The people carefully doubled each dimension of the altar, but the plague continued; doubling each edge had increased its volume eightfold rather than twofold. The plague ran its natural course. The Athenians nevertheless continued their attempts to solve the "Delian problem." Not until some 2,000 years later was it recognized that the oracle had sardonically proposed an unsolvable problem.

The Delian problem amounts simply to solving the equation $x^3=2$, but this could not be accomplished by the geometry of the line and circle alone without recourse to arithmetic, as the original restriction dictated. The Greeks were prevented from attempting an algebraic solution, in any case, by a disconcerting discovery which is said to have cost the discoverer his life by shipwreck. A member of the Pythagorean school, one Hippasus, had proved by rigorous reasoning that there is no number that will measure exactly the diagonal of a unit square. The answer to this problem, which is expressed in algebraic terms by the equation $x^2=2$, is an irrational

number. To the Greeks this meant that geometrical problems are not to be solved through arithmetic, and hence they banned from their mathematics the notions of a variable and of an arithmetical continuum—a number system having the same continuity as a line. Consequently the Greeks never developed an algebra appropriate to the methods of coordinate geometry.

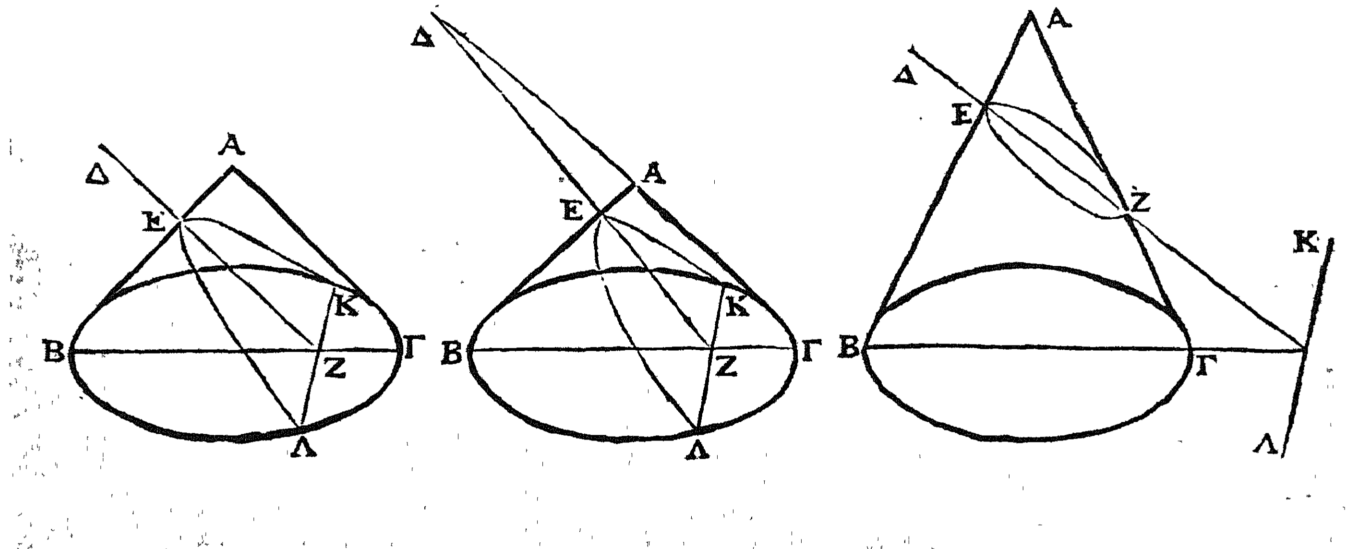
After many fruitless efforts to solve the cubic equation $x^3=2$, the Greeks finally decided to seek a solution by relaxing the rules, permitting curves other than the circle and straight line to be used. But here a peculiar difficulty was encountered. The Greeks were aesthetically one of the most gifted people of all time, yet the only curves that they had observed in the heavens and on the earth were circles and straight lines. The straight and the round seem to have possessed for the Greeks a peculiar fascination, and upon them they sought to build their astronomy and mechanics, as well as most of their mathematics.

Of all curves seen in routine experience, the most common, with the exception of the straight line, is not the circle but the ellipse. Wheels and other circular objects, when viewed obliquely, appear as ellipses, and the shadows cast by circles are practically always elliptical. Yet there appears to be no evidence that the Greeks noticed this ubiquitous curve until they began their relentless search for a geometrical solution of the equation $x^3=2$. It is reported that the ellipse was discovered, together with the hyperbola and parabola, toward the middle of the fourth century B.C. by Menaechmus, tutor of Alexander the Great. Menaechmus is said to have advised his impatient pupil, "There is no royal road to geometry"—all unaware that the three curves he had discovered were to be crucial in the development of analytic methods, a path to geometry far easier than the one he was expounding.

The equations of two of the curves he obtained, the parabola and the hyperbola, would now be written as $x^2=y$ and $xy=2$, respectively. If y is eliminated from these two equations, the result is $x^3=2$. The Delian problem can therefore be solved by finding the point of intersection of these two curves on a coordinate graph (*see diagram on page 44*).

Menaechmus was aware in a general way of the properties expressed by the equations of these curves, but he did not use analytic geometry in the modern sense. Greek study of the so-called conic sections was entirely in the language of pure geometry, without reference to algebraic considerations. The writings of Menaechmus have been lost, so we do not know the precise manner in which he was led to the curves. It seems likely, however, that he discovered them through a consideration of familiar geometrical solids. He may well have obtained the three conic sections by cutting each of three right circular cones—one acute-angled, one right-angled and one obtuse-angled—by a plane perpendicular to one element of the cone. The Greek mathematician Apollonius showed later in his famous *Conics* that by varying the angle of the cutting plane, all three types of curves can be obtained from a single right or oblique circular cone. It was Apollonius who gave the curves their present names—ellipse, parabola and hyperbola, the literal meanings of which are "less than," "the same as," and "more than," respectively. (Three figures of speech—ellipsis, parable and hyperbole—are derived from the same source.)

The word "curve" is difficult to define precisely, for, as the German mathematician Felix Klein wrote, "Everyone knows what a curve is, until he has studied enough mathematics to become confused through the countless number of possible exceptions." Nevertheless, it is sufficient for most purposes to define a curve in a plane as the locus, or totality, of points in the plane which satisfy a given condition—*i.e.*, it is the path of a point which moves according to a given law. The circle, for example, is the locus of all points at a given distance from a given fixed point. The Greeks knew that the locus of a point which moves so that its distance from a given point is in a fixed ratio to its distance from a given line is either an ellipse, a parabola, or a hyperbola, according as the ratio is less than, equal to, or greater than one. Lacking modern algebra, however, the ancients experienced great difficulty in attacking some questions



CONIC SECTIONS, which are curves obtained by cutting a circular cone with a plane, were probably first described by Menaechmus, tutor of Alexander the Great. The three sections are the parabola (1), the hyperbola (2) and the ellipse (3). These illustrations of conic sections are from an edition of the Greek mathematician Apollonius' *Conics*. The edition was brought out in 1710 at Oxford by the English astronomer Edmund Halley.

VIÈTE, a 16th-century counsellor to the King of France, was in the direct line of intellectual descent that led to Descartes. He suggested that vowels be used as the symbols for unknown quantities, and consonants for known.

FERMAT, a contemporary of Descartes, expressed basic principle of analytic geometry: "Whenever in a final equation two unknown quantities are found, we have a locus, the extremity of one . . . describing a line."

involving loci which today even a beginning student of analytic geometry handles with ease.

One of their troublesome problems was the following: Given four fixed lines, to find the locus of a point which moves so that the product of its distances from two of the lines shall be in a fixed ratio to the product of its distances from the other two lines. The locus is in all cases one of the conic sections. The problem has become known as "the problem of Pappus," after the Greek mathematician who called attention to it in the fourth century A.D. This problem and its generalization led Descartes to the development of analytic geometry some 1,300 years later.

THE essential ingredient that made this possible was the development of algebra. Pappus had failed to solve the generalization of his problem for want of algebra, and it was in algebra that the Hindus and Arabs of the medieval period, and the European scholars of the Renaissance or early modern period, were strongest. They took less seriously the distinction that the Greeks had made between the discreteness of number and the continuity of geometrical magnitudes. Algebraic symbols, introduced freely into arithmetic and geometry, were used indifferently to designate either numbers or lines. The Persian poet Omar Khayyám, for example, devised an algebra in which he gave both numerical and geometrical solutions for linear and quadratic equations. It was Descartes who first combined an algebraic study of such equations with the geometrical problem of Pappus, and the result of the combination was analytic geometry. But Descartes was partly anticipated by the medieval Latin theologian Nicole Oresme, who had been thinking along entirely different lines.

Oresme's discovery had to do with something called the "latitude of forms," derived from a study of physical variables. In the 14th century, Scholastics at Oxford and Paris, following up Aristotle's generative idea of change, concerned themselves with problems of varying acceleration, density, thermal content, and intensity of illumination. They distinguished not only between uniform and non-uniform rates of change, but also subdivided the latter according as the rate of change of the rate of change was or was not constant. In their "latitude of forms" concept, a "form" was any variable quantity in nature (such as motion, heat or light), and its "latitude" was the value of this quantity corresponding to a given value of the "longitude" or independent variable (generally time or space). The latitude of forms illustrates the important mathematical concepts of "variable" and "function"—the dependence of one quantity upon another so that a change in the one implies a change in the other.

At first this useful idea was not related to graphical methods. But in the middle of the 14th century Oresme, director of the Collège de Navarre in Paris and later Bishop of Lisieux, hit upon the important idea of clarifying functional relationships through reference to geometrical figures. If, for example, the velocity of an object was to be represented as a function of time, the time units were measured along a horizontal base line (longitudes), and the corresponding velocities were illustrated by lines (latitudes) drawn perpendicular to the base line. The totality of the latitudes or velocity lines constituted the graph of the function. For example, the graph of uniformly accelerated motion is a straight line, as shown in manuscripts describing Oresme's ideas.

Oresme's system of latitudes and longitudes appears to be the earliest use of coordinates in the graphical representation of arbitrary functions. Oresme consequently has been hailed by some historians as the inventor of analytic geometry. The usefulness of his ideas, however, was sharply limited. Although he handled linear graphs correctly, he was prevented by deficiencies in geometrical knowledge and algebraic technique from extending his novel idea to curvilinear figures. There is in his work no systematic association of algebra and geometry in which an equation in two variables determines a specific curve, and conversely.

Because Descartes carefully avoided any reference to his predecessors, one cannot say with assurance that he was familiar with the work of Oresme. It seems quite probable that he was. Yet the differences between Descartes' system, called

DESCARTES, a philosopher who utilized mathematics as a basis for rational thought, apparently was not fully aware of the importance of analytic geometry. His concept appeared as appendix to philosophical work.

EULER, a mathematician who was born in Switzerland, lived in Germany and died in Russia, published the first textbook of analytic geometry more than a century after the appearance of Descartes' original principles.

Cartesian geometry, and the graphical representation of the latitude of forms are so great as to make questionable any decisive influence. While Descartes was perhaps slightly in debt to Oresme, the immediate inspiration for his work came not from the 14th-century Bishop of Lisieux, but from a 16th-century counsellor to Henry IV of France named François Viète.

Viète's contribution was the simplification and systematization of algebra by the invention of certain symbols and ideas. The signs + and — had already been substituted for the words plus and minus at the time of Columbus, and half a century later the symbol = for equality had been introduced in England But convenient notations for the quantities entering into an equation were lacking. Viète suggested that unknown quantities be designated by vowels, and that quantities assumed as known be represented by consonants. This made algebra more than arithmetical legerdemain, for it became a systematic study of types or forms. Equations with numerical coefficients gave way to equations with literal coefficients. Where previously attention had been centered upon the construction of the roots of a particular cubic equation, such as $x^3=2$, Viète showed that the solutions of *all* cubic equations were reducible to the Delian problem of duplicating the cube, or to the trisection of an angle. Geometric problems could be expressed in the language of algebra; and, after algebraic simplification, the roots of the resulting equations could be constructed geometrically

The application of algebra simplified geometry to a great extent, yet Viète did not discover the royal road for which Alexander had hoped. Oresme had missed the invention of analytic geometry because he had had no algebra adequate to the study of graphical representation; Viète, however, failed to associate his algebraic geometry with a coordinate system.

BUT the stage was set for someone to fuse algebra and geometry through the crucial idea of coordinates, and the result was one of the many cases in science and mathematics of simultaneous discovery. Analytic geometry was the independent invention of two Frenchmen who were the greatest mathematicians of their day, yet neither of whom was a professional in the field. Pierre de Fermat was a lawyer with an absorbing interest in the geometrical works of antiquity; René Descartes was a philosopher who found in mathematics a basis for rational thought. Both men began where Viète had left off, but they continued in somewhat different directions. Fermat retained the notation of Viète, but applied it in a new connection: the study of loci; Descartes adopted the aim of Viète—the geometric solution of algebraic equations—but extended it, in conjunction with modern symbolism, to equations of higher degree.

Fermat composed in Latin only a very short treatise on analytic geometry—*Introduction to plane and solid loci*. It is a work of but eight folio pages, devoted to the line, circle and conic sections. It opens with the statement that although the ancients studied loci, they must have found them difficult, judging from the fact that they often failed to state the problem in general form. Fermat proposes to submit the theory of loci to an analyis that is appropriate to such problems and that will open the way for a general study of them. Without further introduction, he then states in clear and precise language the fundamental principle of analytic geometry.

> *Whenever in a final equation two unknown quantities are found, we have a locus, the extremity of one of these describing a line, straight or curved.*

This brief sentence represents one of the most significant statements in the history of mathematics. It introduces not only analytic geometry, but also the immensely useful idea of an algebraic variable. The vowels in Viète's terminology previously had represented unknown, but nevertheless fixed or determinate, magnitudes. Fermat's point of view gave meaning to indeterminate equations in two unknowns—which previously had been rejected in geometry—by permitting one of the vowels to take on successive line values (corresponding to Oresme's longitudes), and plotting the values of the other as perpendicular lines (latitudes, Oresme would

have called them). Thus Fermat rediscovered the graphical representation of variables, and this time there was an algebra at hand with which to exploit the idea.

Fermat showed that equations of the first degree, which today are expressed in general terms as $ax+by+c=0$, represent straight lines; equations of the second degree of the form $x^2+y^2+ax+by+c=0$ represent circles; other equations of second degree represent ellipses, parabolas, and hyperbolas. As the "crowning point" of his treatise, Fermat gave the following proposition:

> *Given any number of fixed lines, the locus of a point which moves so that the sum of the squares of the segments drawn at given angles from the point to the lines shall be constant is a conic section.*

Fermat's analytic geometry was not published during his lifetime, so it is difficult to determine the extent of its influence. The *Introduction* appeared in print for the first time in 1679, 14 years after the death of its author, 40 years after the publication of the corresponding work of Descartes, and half a century after the treatise had been composed. Manuscript works of that day often enjoyed a wide circulation among scholars, but readers of Fermat's work, unaware of the early date of its composition, missed its significance as evidence of his independent invention of analytic geometry. Hence analytic geometry came to be known as "Cartesian geometry." This designation is perhaps not entirely unwarranted, for it was largely through the influence of Descartes, rather than of Fermat, that the new geometry took root.

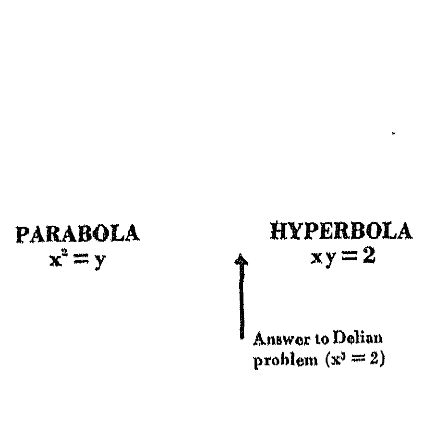
Descartes' only work on the subject, *La géométrie*, appeared somewhat unobtrusively in 1637, as an appendix to the longer and better-known philosophical treatise, *Discours de la méthode pour bien conduire sa raison, et chercher la vérité dans les sciences*. The whole was published without the author's name, although the authorship was generally known.

The theme of *La géométrie* is set by the opening sentence:

> *Any problem in geometry can easily be reduced* [algebraically by means of coordinates] *to such terms that a knowledge of the lengths of certain lines is sufficient for its construction.*

Descartes was concerned primarily with the geometric solution of equations; indeed, he was a direct descendent of those who, more than 2,000 years before, had attempted to appease the oracle of Apollo at Delos. This concern was reflected in his treatise. Book I is on "problems the construction of which requires only straight lines and circles"—the original Greek limitation on constructions. The goal of the treatise—the third and last book—is on the geometric solution of equations of degree higher than two. The really important, modern part of his work, Book II, which deals with "The nature of curved lines," was dismissed by Descartes as a preliminary to Book III. It is paradoxical that Descartes, from whom the world derived coordinate geometry, showed little interest in this basic principle; he used coordinates simply as an aid to the solution of geometrical problems, and was so indifferent to the theory of curves that he never fully understood the significance of negative coordinates.

Descartes had been much impressed by the power of his method in dealing with the locus of Pappus, and this problem runs like a thread of Ariadne through the three books of *La géométrie*. His fundamental



COORDINATES of analytic geometry make it possible to solve the problem stated by oracle of Delos.

principle of analytic geometry is enunciated in Book II in this way:

> *For the solution of any one of these problems of loci is nothing more than the finding of a point for whose complete determination one condition is wanting . . . In every such case an equation can be obtained containing two unknown quantities.*

This crucial statement means that an equation in two unknowns in general represents a curve. For example, the equation $xy=x^3-2x^2-x+2$, which appears repeatedly, represents what Isaac Newton later called the "Cartesian parabola" or trident.

The loci in Pappus' problem for the case of four lines lead to equations of the first and second degree. Descartes showed that for five, six, seven or eight lines the locus is a curve of degree three or four; and in general if the number of lines does not exceed 2n, the degree of the locus will be not more than n. Descartes was not much concerned, however, with the shape of these curves or loci; he wished to use them to solve, graphically, algebraic equations in a single unknown. But here Descartes made a bad blunder. The Pythagoreans knew that equations of degree one or two could be solved by straight lines and circles alone; Menaechmus, Omar Khayyám and Viète knew that equations of degree three or four could be solved by conic sections, *i.e.*, by curves of order two. Descartes extrapolated too rapidly and asserted that equations of degree 2n or 2n—1 require, for their graphical solution, curves of order n. This would mean, for example, that an equation of degree nine, such as $x^9+x+1=0$, called for curves of order five, whereas actually the cubic curves $y=x^3$ and $y^3+x+1=0$ suffice, through the elimination of y, to solve the equation. As Fermat and others pointed out, the correct rule is that equations of degree not exceeding n^2 are solvable by means of curves of order not greater than n.

Estimates of the relative merit of the works of Fermat and Descartes differ widely, partly because of differences encountered in notation, emphasis and point of view. The algebraic notation of Descartes was far more appropriate than that of Viète and Fermat. To Descartes we owe the use of letters near the end of the alphabet—such as x, y and z—to represent unknowns, and of letters near the beginning of the alphabet to represent known quantities. The immensely convenient notation of exponents for powers (x^2, y^3, etc.) was also introduced by Descartes. On the other hand, the fundamental idea of the equation of a curve is more clearly set forth by Fermat. The work of Descartes is more general in scope, that of Fermat being limited to equations of first and second degree; but the expository treatment of Fermat's *Introduction* is more systematic than that of Descartes' *La géométrie*. One gets the impression that Descartes wrote his geometry to boast rather than to explain. He built it about a difficult problem (the Pappus locus), and he did not go into detail to make his argument clear. In concluding the work he justifies this inadequacy of exposition by the remark that he has left much unsaid in order not to rob the reader of the joy of discovery. In so doing, however, he deprived many a student of the milder pleasure of comprehension. Descartes might better have followed his own advice: "When you have to deal with transcendent questions, you must be transcendently clear."

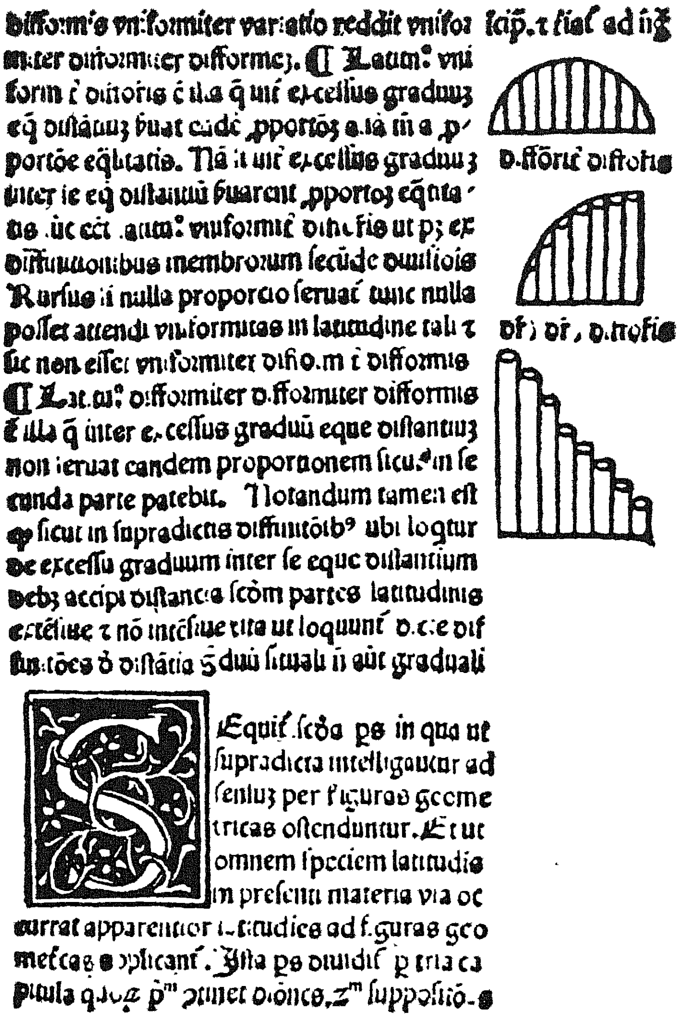
THE geometry of Descartes and Fermat did not bring about a rapid transformation of mathematics. For one thing, the haughty attitude of Descartes and the indifference to fame of Fermat made the new subject accessible almost exclusively to professional geometers of marked ability. (The incomparable Newton quickly mastered analytic geometry and extended it to include the general theory of curves.) So, although analytic geometry had been twice invented before 1637, it was not until more than a hundred years later, in 1748, that what may be called the first

textbook on the subject appeared This treatise, the *Introduction to infinitesimal analysis* of Leonhard Euler, was written in Latin by a mathematician who was born in Switzerland, lived in Germany and died in Russia. The work remains a classic, yet it has never been translated into English. To the contributions of Fermat, Descartes and Newton, Euler added a significant achievement of his own: he extended Cartesian geometry to the space of three dimensions.

In the end, it was a practicing revolutionist who brought analytic geometry into general use. This was Gaspard Monge, a Frenchman who participated in three "revolutions." As an ardent republican, he took an active part in the affairs of the French revolutionary government, and later was closely associated with Napoleon. As an experimental chemist, he shared the credit for the discovery of the composition of water, a keystone in the chemical revolution. But primarily he was a mathematician, the foremost specialist of his day in geometry, and it was he who saw, more clearly than others, that analytic geometry differs from synthetic geometry as one language does from another. Both say the same thing in different ways. Pure or synthetic geometry is expressed by means of diagrams and constructions, analytic geometry, in terms of algebra and equations. Monge therefore suggested to his students at the famed École Polytechnique that the elementary geometry of lines and planes, of circles and spheres, is quite as appropriately studied by analytic means as are the more advanced properties of the conic sections. This view resulted in a transformation of Cartesian geometry that was every bit as striking in its way as was the new chemistry of Antoine Lavoisier; hence the phrase "analytical revolution" may aptly be applied to the movement initiated by Monge.

There is considerable justification for the proposition that analytic geometry is primarily a French contribution. Its two most important modern precursors, Oresme and Viète, were French; so were its two inventors, Fermat and Descartes, as well as Monge, the man who together with his disciples did most to fashion Cartesian geometry into modern form. On the other hand, the multitudinous developments of the past hundred years have been contributed by men of all nationalities. Indeed, the most noteworthy accounts of the development of analytic geometry are not by Frenchmen but by an Italian, two Germans and an American. These four scholars—Gino Loria, Johannes Tropfke, Heinrich Wieleitner and Julian Coolidge—are symbols of the fact that in mathematics the one-world ideal is not a mirage.

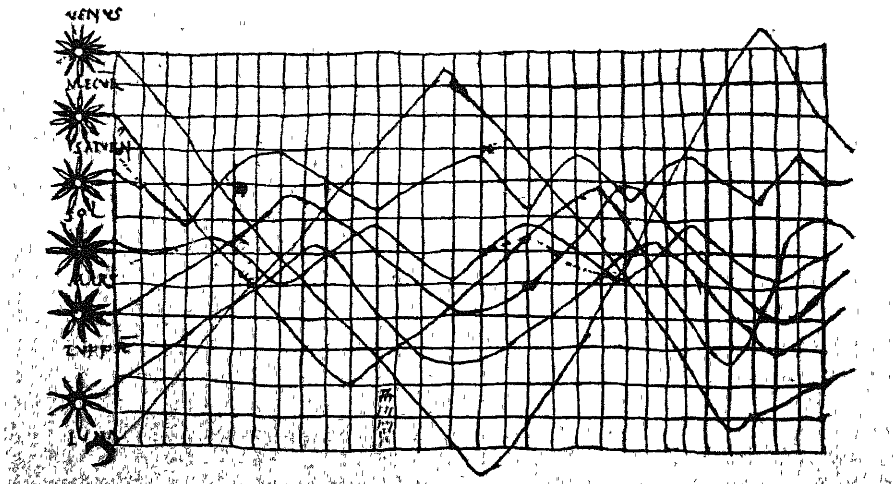
Carl B. Boyer is professor of mathematics at Brooklyn College.



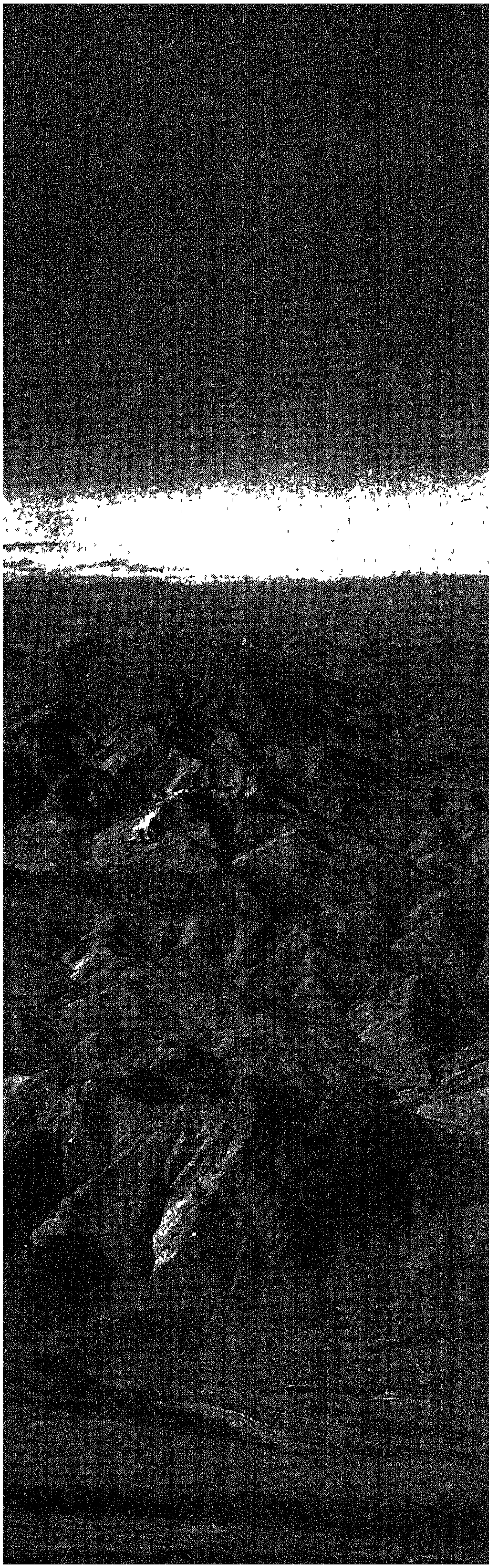
difformis vniformiter variatio reddit vnifor miter difformiter difformem. ¶ Latitudo vni formis difformis est illa que inter excessus graduum eque distantium servat eandem proportionem equalitatis. Nam si inter excessus graduum inter se eque distantium fuerit proportio equalitatis ... vniformiter difformis ... in distantiis membrorum secundum divisiones. Rursus si nulla proportio servatur tunc nulla posset attendi vniformitas in latitudine tali et sic non esset vniformiter difformis ... ¶ Latitudo difformiter difformis est illa que inter excessus graduum eque distantium non servat eandem proportionem sicut in secunda parte patebit. Notandum tamen est quod sicut in supradictis diffinitionibus ubi loquitur de excessu graduum inter se eque distantium debet accipi distancia secundum partes latitudinis extensive et non intensive ...

Sequitur secunda pars in qua ut supradicta intelligantur ad sensum per figuras geometricas ostenduntur. Et ut omnem speciem latitudinis in presenti materia via occurrat apparentior latitudines ad figuras geometricas applicantur. Ista pars dividitur per tria capitula ...

MATHEMATICAL FUNCTIONS, magnitudes which relate one changing quantity to another, were first represented graphically in a book written in 14th century either by the theologian Nicole Oresme or one of his students.



USE OF COORDINATES, one of the fundamental concepts of analytic geometry, is of great antiquity. This sketch of the paths of the sun, moon and planets was drawn in the 10th century. Symbols of these bodies are at the left.



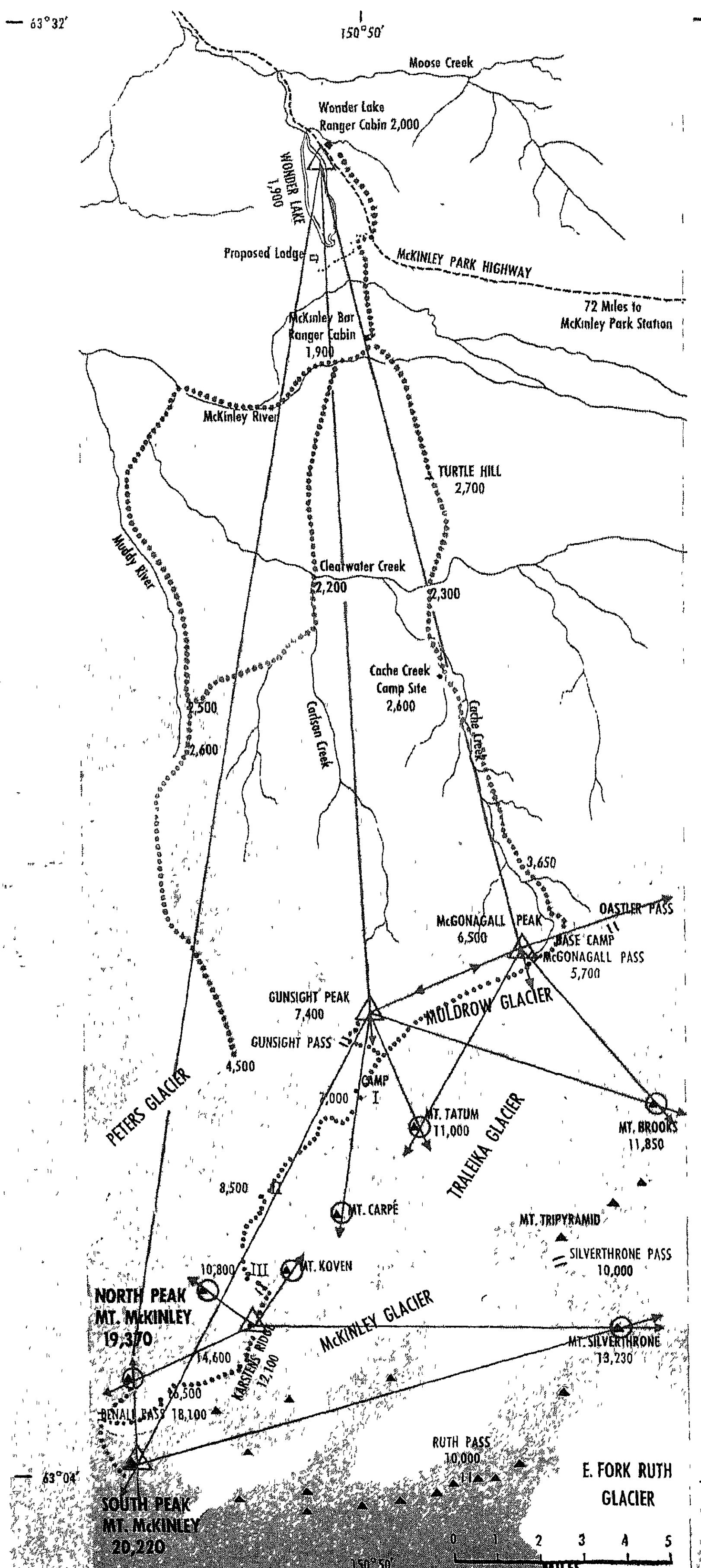
Mapping Mount McKinley

Highest peak in North America was scaled by survey party to locate its features accurately

by Bradford Washburn

MOUNT McKINLEY, the 20,000-foot giant of Alaska, is not only the highest peak in North America, it is probably the highest mountain mass anywhere on earth that rises out of a level plain. It was first climbed in 1913 by Archdeacon Hudson Stuck, who took nearly three months to do the job. It has now been climbed six times. The hiking distance from the end of the nearest road to the mountain's peak and back is 80 miles, half of which is over perpetual snow and ice. The mountain itself is a vast wilderness of frigid peaks and glaciers Even in midsummer the day and night average of the temperature at the summit is less than 20 degrees below zero.

Until recently no serious attempt had ever been made to map the mountain; even military reconnaissance planes habitually by-passed it. Some people may wonder why anyone should want to map that desolate spot. There are several excellent reasons. One is that the upper slopes of McKinley are an ideally rigorous place for all sorts of cold-weather tests and experiments. During the recent war the mountain and its approaches were used three times for tests of Army equipment. Another reason is that because of its height and extreme northern latitude McKinley is an excellent location for the study of weather and cosmic rays. A third reason is that the peak is the chief attraction of Mount McKinley National Park New roads and railroads will before long bring vacationers and mountaineers to it. Once extremely difficult to approach, McKinley has now become one of the most



PRELIMINARY MAP of Mount McKinley shows approximate location of its various heights and routes taken by the surveying party. Triangles indicate the points from which sights were taken. Circles show the peaks sighted.

accessible of the world's great peaks. A good road reaches to Wonder Lake, only 20 miles north of the base of the mountain.

I became acquainted with the mountain in 1936, 1937 and 1938, when I made a number of flights over and around it for the National Geographic Society. The aerial photographs then taken were later invaluable to an Army expedition which tested winter clothing and equipment on McKinley in 1942 and to which I was assigned as a representative of the Air Force. This expedition, and a second one to nearby Mount Silverthrone in 1945, gave me a strong desire to get back into the Alaska range again some day. The grandeur of those great peaks is unforgettable, and the fact that they were virtually unmapped was something of a challenge.

A year ago the opportunity came. RKO Radio Pictures asked the Boston Museum of Science to cosponsor an expedition to climb and photograph Mount McKinley; in return we received sufficient funds for an extensive scientific study of the mountain. After months of preparation, in which we had the assistance of the Coast and Geodetic Survey, the Alaskan Air Command, the Signal Corps, the National Park Service, the Weather Bureau and the Geological Survey, our party of 13, including my wife, arrived at McKinley in April of 1947 for "Operation White Tower." It was not organized to break a speed record; we spent 93 days climbing over and surveying McKinley's peaks.

MAPPING a mountain is a specialized job. As a preliminary, B-29s of the 46th Reconnaissance Squadron photographed the entire area from 32,500 feet. Their stereoscopic pictures depicted clearly every detail of the inconceivably complex system of peaks and valleys. One may ask: Why *climb* McKinley to map it if every inch of its slopes had already been accurately photographed? The answer is that although aerial photographs can be scaled and converted into a reasonably good map without any ground work, a really accurate map requires a framework of triangulation, or what is called ground control. Ground control is to an accurate map what the steel framework is to a completed skyscraper.

Needless to say, it is not necessary to climb every peak in a range to map it precisely. By observations with an accurate surveying instrument from a few carefully chosen points, the positions and altitudes of hundreds of other points can be computed by trigonometry. On McKinley our basic starting points were four prominent peaks, the positions and altitudes of which had previously been determined by the Coast and Geodetic Survey from distant observing stations during the mapping of the Alaska Railroad. We planned to occupy three of these peaks and sight from them.

My assistants in the actual surveying were Robert Lange, a geology student at

the University of New Hampshire, and Lieut William Hackett, the Army's representative on the expedition. We worked with two extremely accurate theodolites loaned by the Coast Survey. Our work was carried out almost constantly under the most frigid and miserable conditions imaginable.

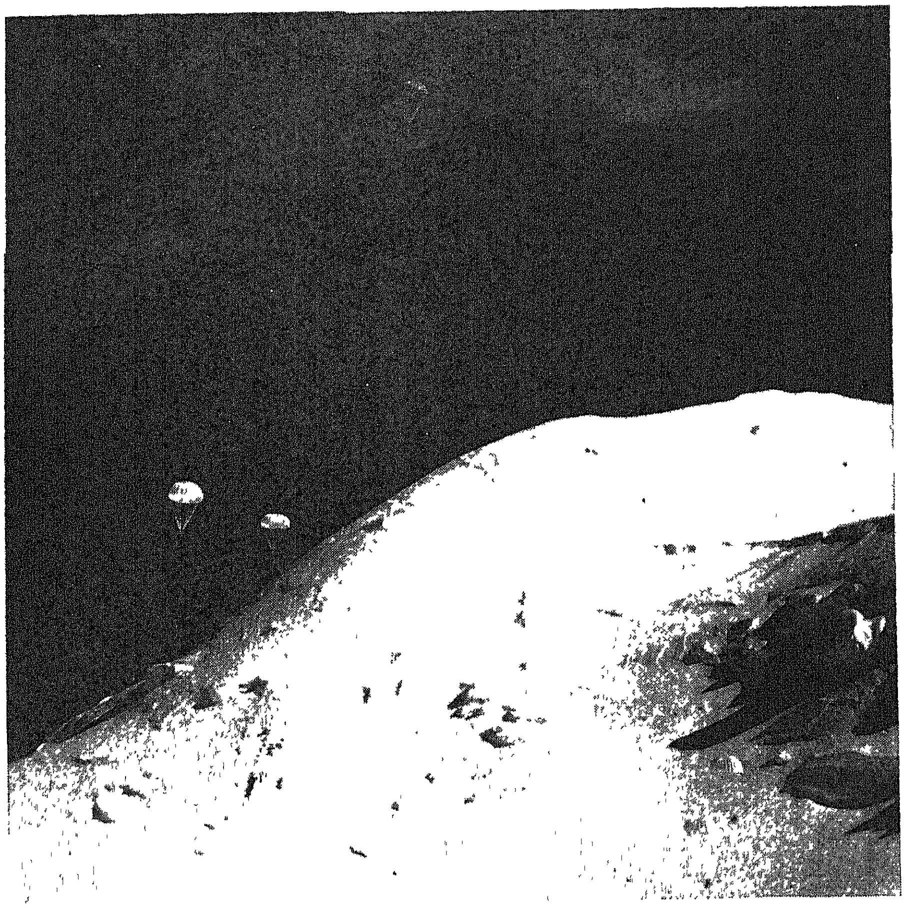
It is well-nigh impossible to operate a delicate theodolite with gloves on. Because bare metal cannot be safely touched with ungloved hands in sub-zero weather, we covered the tangent screws, leveling screws and other adjustable parts with adhesive tape. I worked with my left hand in a big mitten and my right completely bare. After three or four minutes I would put my bare hand under my armpit to warm it while the recorder checked his figures. Then I'd go to work again after three or four minutes' warm-up. Lange and Hackett took turns at recording the observations in our angle-book, changing places as their fingers became too numb to write

Cold itself is a less insidious deterrent to good work than the sloppiness and lack of ambition brought about by high altitude. Our stations atop McKinley's two principal eminences, the North and South Peaks, were both a mile higher than any survey station ever before occupied in North America. There was no practical way of providing oxygen for our party, so we did everything on what nature provides up there—less than one half the supply of oxygen we breathe at sea level To prevent errors, we developed a fixed routine for setting up our instrument, freezing it in place, leveling it, observing and recording —so after a time we did almost everything by force of habit. Setting up the tripod rigidly is vital for accuracy in this work. Sometimes we brought along a vacuum bottle full of warm water with which to freeze the tripod legs firmly into the snow. No matter how carefully we stamped and froze the tripod legs into the ground, however, some errors always crept in when the instrument was set up on snow instead of rock or ice. Consequently all key observations were checked and double-checked for collimation error right on the spot.

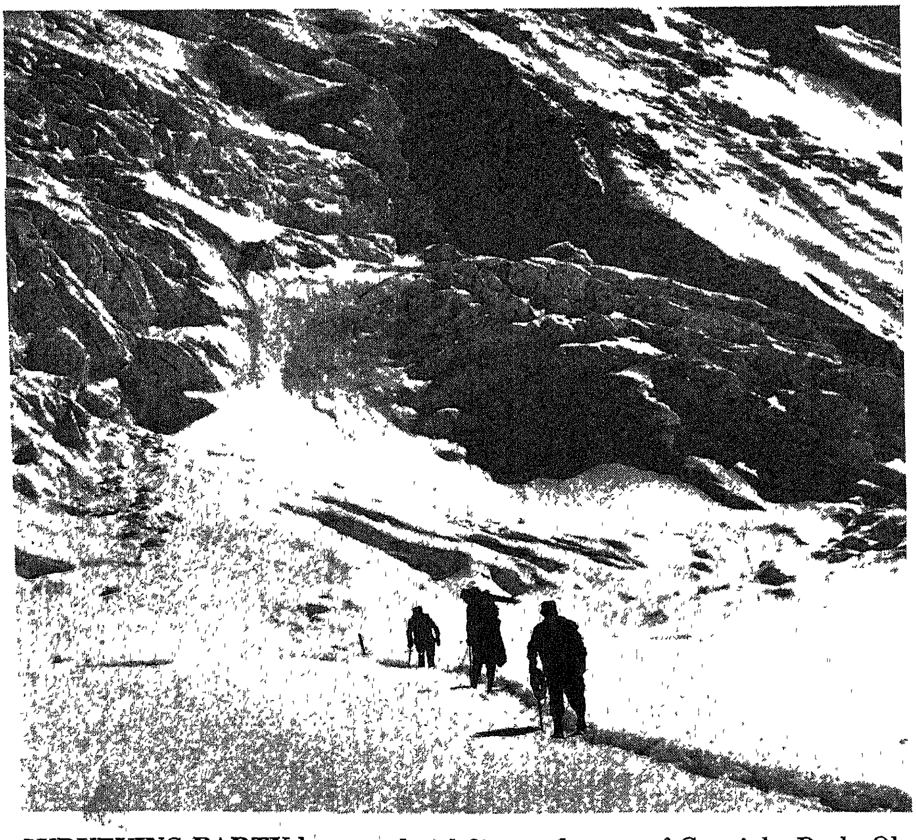
We had promised the Geodetic Survey that we would try to carry out observations from the tiptop of both of McKinley's peaks and from Denali Pass, the notch between them. We knew that these figures would not only determine accurately the relative altitude of the two peaks but strengthen the precision of the whole job.

The top of McKinley's South Peak, the 20,220-foot high point of the mountain, was the most trying survey job, even though we were there but 40 minutes and observed only three directions and two vertical angles. It was 20 below zero with a gusty 20-to-30-mile breeze blowing. Occasionally, while I was observing, abrupt gusts of wind would bump my face against the eyepiece of the theodolite. Then I would have to recheck the level and swing

FINAL CAMP OF CLIMB was below McKinley's South Peak, which is just out of the picture to the left. The four tiny figures which appear at the bottom are just leaving the camp to begin the ascent of the South Peak.



PARACHUTES DESCEND bearing apparatus for observing cosmic rays. At right is South Peak. Expedition's cosmic-ray station was at 18,000 feet. Northern latitude gave chance for unusually significant observations.



SURVEYING PARTY bears a theodolite to the top of Gunsight Peak. Observers tried to set up theodolites on ice or rock. When they could not, they carried vacuum bottles of warm water to freeze tripod legs in snow.

back to the first station observed to make sure that the bump had not moved the tripod a hair.

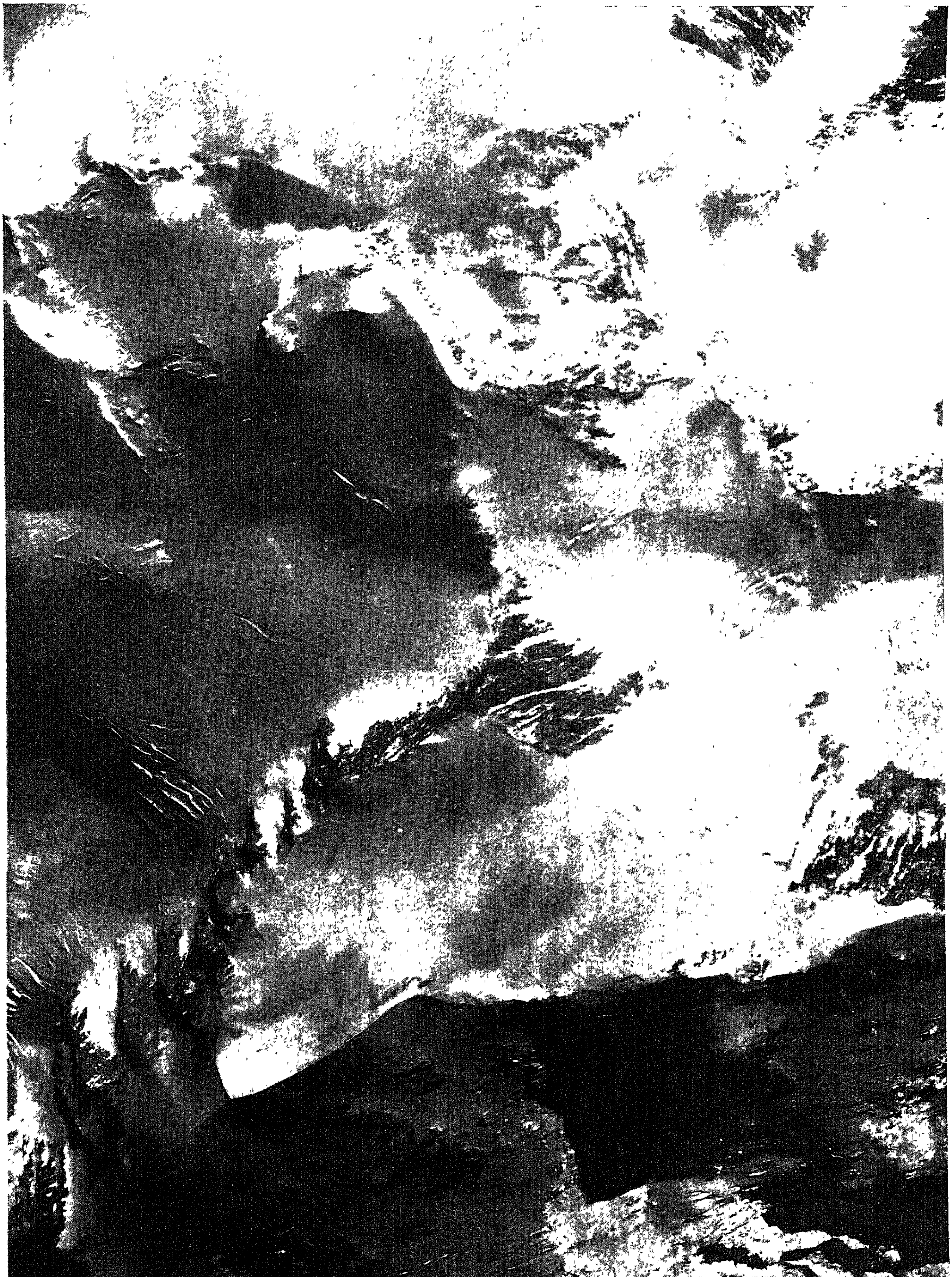
On the summit there was not an inch of shelter anywhere The topmost drift was streamlined and packed as hard as concrete My eyelashes were covered with frost feathers from my breath, and frost clouded the telescope eyepiece The conditions were so bitter that even with clothes that would normally have kept us comfortably warm at 40 below, we were chilled to the marrow.

The following day, atop the North Peak only about 800 feet lower, there was not a breath of wind from sunrise to sunset! The weather was so clear and quiet that, tired as we were when we reached the top, we set up the instrument the moment we arrived and busily observed all our important angles before having a bite to eat. We couldn't believe that such weather could last more than an hour or two We stayed on top for three full hours. It was warmer than the day before—about zero. When we lunched at three o'clock, the afternoon sun was really warm and pleasant. As we sat there on a steep snowdrift 19,370 feet above the sea, and just south of the Arctic Circle, it was so still that the open pages of our angle-book did not even move. It was rare, incredible weather for McKinley.

THE North Peak summit is very different from the South Peak The top of the latter is a large, dome-shaped drift; the North Peak ends in a sharp little point, with a fantastic drop on the northern side. To get leveled up squarely over the top, we first poked a vertical hole deep into the hard snow of the exact point. Then we cut away the tip of the point with our ice axes to make a flat, triangular station, found the hole again, and plumbed the theodolite exactly over it. I had to move around very gingerly, especially while I was on the north side of the instrument looking at the South Peak The flat station was so small that if I had taken a single careless step backward at that moment I would have fallen at least 14,000 feet.

After three months on the mountain, during which we became familiar with every detail of the peak, we completed our job by taking observations from lowland stations. The key fixed point was at Wonder Lake We were able to make enough observations to warrant a considerable degree of confidence in the results. The new map of McKinley is now being drafted from our observations by computers of the Coast and Geodetic Survey and photogrammetrists at the Geological Survey laboratories in Denver It is scheduled to be issued in 1950.

Bradford Washburn is director of the Boston Museum of Science and a former teacher of surveying at Harvard University.



AERIAL PHOTOGRAPH of McKinley shows the mountain from a point directly above its summit. At the lower left is North Peak. Just on the edge of the photograph at the upper left is South Peak. This photograph, made by the 46th Reconnaissance Squadron of the Air Force, shows a vertical relief of more than 12,000 feet.

THE RECORD OF HUMAN ILLNESS

The study of bones indicates that uncivilized man's life was not a perfect idyll of health. He suffered a respectable assortment of diseases and disabilities

by Wilton M. Krogman

AMONG the illusions of civilized man, one of the most unreasonable is that his bodily ills derive mainly from a deplorable decline in the rigor of his existence. To nature lovers from Jean Jacques Rousseau to Bernarr Macfadden, the apotheosis of human physical perfection seems to have been the noble savage—that happy creature who knew no toothache, no rheumatism, no tuberculosis, no sniffling colds This idyllic fancy of course betrays a lack of acquaintance with primitive man in the flesh. The truth is that our prehistoric ancestors, even before contamination by civilization, were just about as subject to disease as we are. Indeed, they were afflicted by many of the same ailments, as we are now learning by close inspection of their readable remains.

We have only their bones to read, but the bones of man are a durable record of his health and his disease, they tell how long he lived, and often how he died. Thus from the skeletal remains available to us we can trace back for nearly a million years part of the record of early man's physical tribulations

The record is naturally limited to the illnesses and mishaps that affected the bones and teeth. The evidence is sufficient, however, to indicate that the Pandora's box of germ diseases was not opened by civilization; our prehistoric parents had their share of these infections. And the law of gravity has always operated; in the Old Stone Age, as now, people fell and broke their bones.

What do the bones of early man have to tell us about the state of his health?

Probably the most universal skeletal affliction of modern man is rheumatism or arthritis—inflammation of the joints. It appears that this disease was also very common among our cave-dwelling forefathers. Man has never escaped arthritis; whatever the climate, diet or living conditions, the joints of the vertebrate skeleton have always ached, creaked and stiffened. (Indeed arthritis can be traced back to the dinosaurs, the giant reptiles of almost half a billion years ago; imagine a Brontosaurus with an 80-foot backbone racked with arthritic pain!) The famous Neanderthal man found at La Chapelle in France had a case of arthritis so severe that the vertebrae in his neck were joined into one solid piece of bone, and so were those in his waist. Human skeletal remains from the Old Stone Age are too scanty to indicate how prevalent arthritis was among this Neanderthaler's contemporaries. But by the opening of the New Stone Age in Europe about 10,000 years ago, the disorder is found to be widespread. Perhaps one adult in four had arthritis, especially of the knee, shoulder and hip joints. By the dawn of recorded history, among the Egyptians of about 5,000 years ago, a middle-aged adult free from arthritis was almost the exception. Nearly as high a frequency has been found among pre-Columbian American Indians.

Much the same is true of tooth decay, another universal affliction which may be classified with arthritis as a skeletal disease; indeed, many doctors and dentists believe that bad teeth and arthritic pains are somehow related. Dental disease has been called a "curse of civilization" by many dietitians and oral hygienists, and it is a fact that the incidence of tooth decay has increased with man's biosocial evolution. The advertisement that shows a beautiful girl gnawing a huge bone, with the caption, "Society says no, but Nature says yes," actually has some basis The distribution of tooth decay, however, is not a matter of all or none—all in modern times, none in prehistory. Among individuals of the Old Stone Age of Europe 50,000 or more years ago whose skeletons have been found, 10 to 40 per cent, depending on the population sample studied, had decayed teeth. Of the skeletons of the New Stone Age of Europe, about 10,000 years ago, 30 per cent had decayed teeth; in the Bronze and Iron Ages of Europe, up to about 4,000 B.C., 40 per cent; among pre-Columbian American Indians, 20 to 75 per cent—the latter in a southwestern U.S Pueblo population subsisting largely on maize. These figures do not compare with the prevalence of tooth decay today in the U.S, where an adult with a perfect dentition is almost a museum specimen, but they do show that bad teeth cannot be blamed entirely on modern foods.

Dental or oral disease may often lead to middle-ear or mastoid infections This was as true in the Paleolithic Era as it is today. The well-known Neanderthal man of Rhodesia, South Africa, who during his lifetime lost or had dental caries in 13 of his 16 upper teeth, shows a perforation in the mastoid process that looks much like the drainage wound of an abscess. If this diagnosis is correct, his is the oldest mastoid case on record.

ANOTHER disorder common to the Neolithic and the Atomic ages which, like arthritis, involves the calcium balance in the body, is arteriosclerosis, or hardening of the arteries Sclerotic plaques, or pieces of hardened aortic artery, have been found in a pre-Columbian Indian burial ground in Kentucky. When Moses appealed to Pharaoh to let his people leave Egypt, it may be remembered, the Lord "hardened his [Pharaoh's] heart." The great Egyptologist Sir Grafton Elliot Smith actually found evidence of cardiac sclerosis—hardening of the heart—in a Pharaoh's mummy!

There is one bone pathology that we share not only with our Stone Age ancestors but with all other mammals—that is, fractures. Our tree-dwelling cousins, the anthropoid apes, often break their arms and legs accidentally. But when we come to early *Homo sapiens* we find something new: fractures inflicted intentionally. It appears that the habit of breaking the bones of other individuals in the same species is one of the features that distinguishes man from the apes. Or to put it another way, early man often used his brains to brain his fellow man.

The skulls of many of our ancestors bear eloquent evidence that early man knew

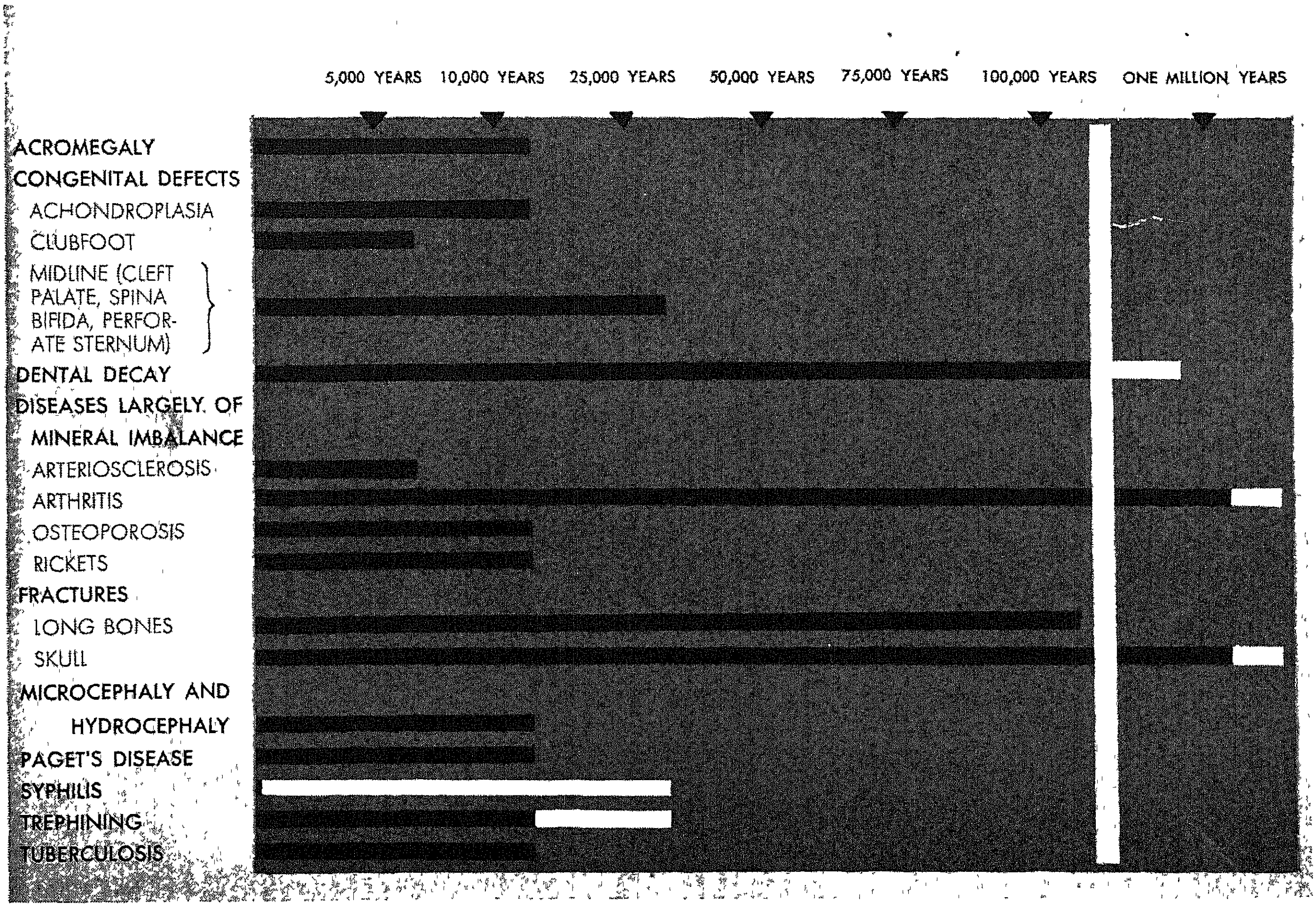
where to deal a lethal blow. Depressed and radial skull fractures are common among the prehistoric populations of the Old and New Worlds. In the Old World, the noble savage used stone clubs to break an enemy's head; in the New World, he used stone axes, wooden clubs and six-rayed maces. Each weapon left a distinctive type of fracture—a trademark preserved for interpretation thousands of years later by anthropologists The skull fractures probably were sustained in two ways: in battle and in ceremonial sacrifice. Enemies who were taken prisoner often were offered to the gods as part of the ritual of victory. It appears also that the heads may have been used in ritualistic cannibalism; the brain was eaten by the victors in order to partake of the "spirit" of a brave slain foe. This custom may be as old as man himself, since skulls a million years old show signs of fractures that suggest smashing to get at the brain.

The frequency of head wounds accounts for the fact that one of the earliest surgical techniques developed by man was that of trephining, *i.e.*, an operation upon the skull to relieve pressure caused by broken bones or concussion. There is evidence of healed operations of this type in skulls more than 10,000 years old, from the New Stone Age of France The prehistoric Incas of Peru were past masters of this early operation. Some Inca skulls show no fewer than four successful operations.

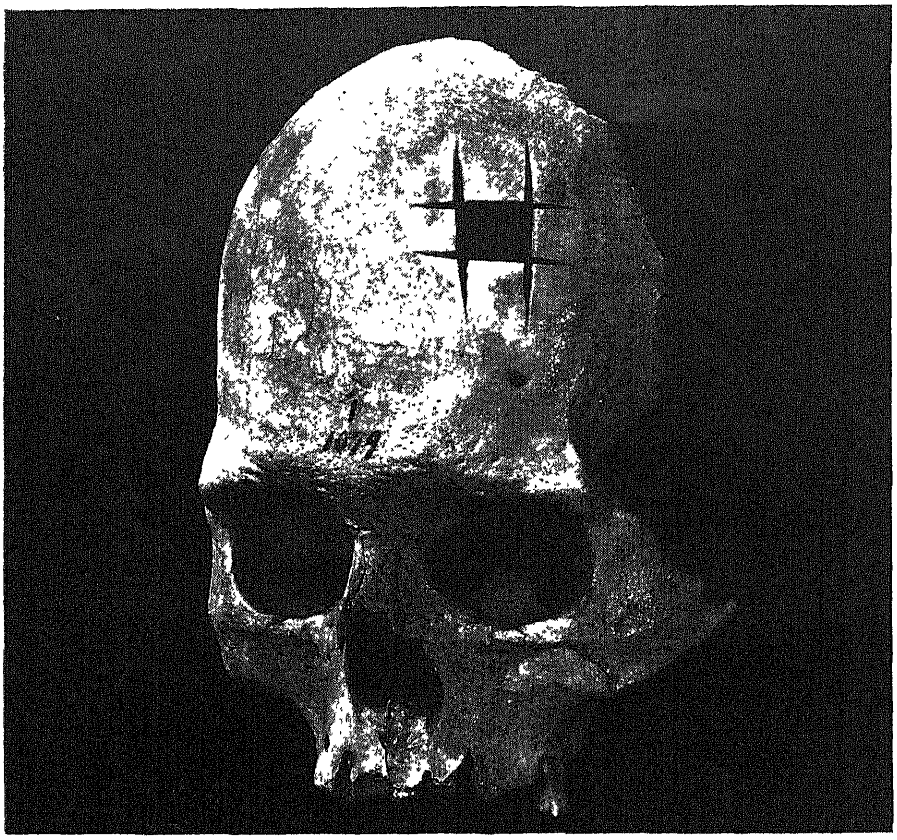
Skeletons of the New Stone Age of Europe show another significant phenomenon: an unusually high percentage of fractured forearms. They are of such a nature as to suggest that the forearm bones (the radius and ulna) were broken while the arm was upraised in an effort to fend off a blow directed at the head. These fractures are most frequent in female bones—tangible evidence that the cave man was rough with his cave woman.

When it comes to infectious diseases, the most controversial question is: Do the bones of prehistoric man show evidence of syphilis? On this infection, which the famous physician Sir William Osler called "the great imitator" because its symptoms simulate so many other diseases, there are two sharply divided schools of thought: one contends that the disease did not exist before the discovery of the New World; the other argues that it did. Some French pathologists assert that certain skulls of the New Stone Age, at least 10,000 years old, show lesions similar to those produced by syphilis. It is also claimed that a late Old Stone Age site at Solutré, in France, yielded 25,000-year-old shinbones with syphilitic lesions. Within historic times syphilitic bones are reported for Roman and medieval Europe, for early dynastic Egypt (about 2,500 B.C.), for New Stone Age Japan and India In the Western Hemisphere they are reported for pre-Columbian Peru, Mexico, and the southwest of North America. Yet the question remains unresolved: perhaps the best we can do on the basis of present evidence may be summarized by a report the writer has made on some 5,000-year-old bones from ancient Iran. There a forearm bone was found that showed a symmetrical periostitis (inflammation of the vascular membrane). It looks like syphilis, but "looks like" is about as close a diagnosis as may be ventured.

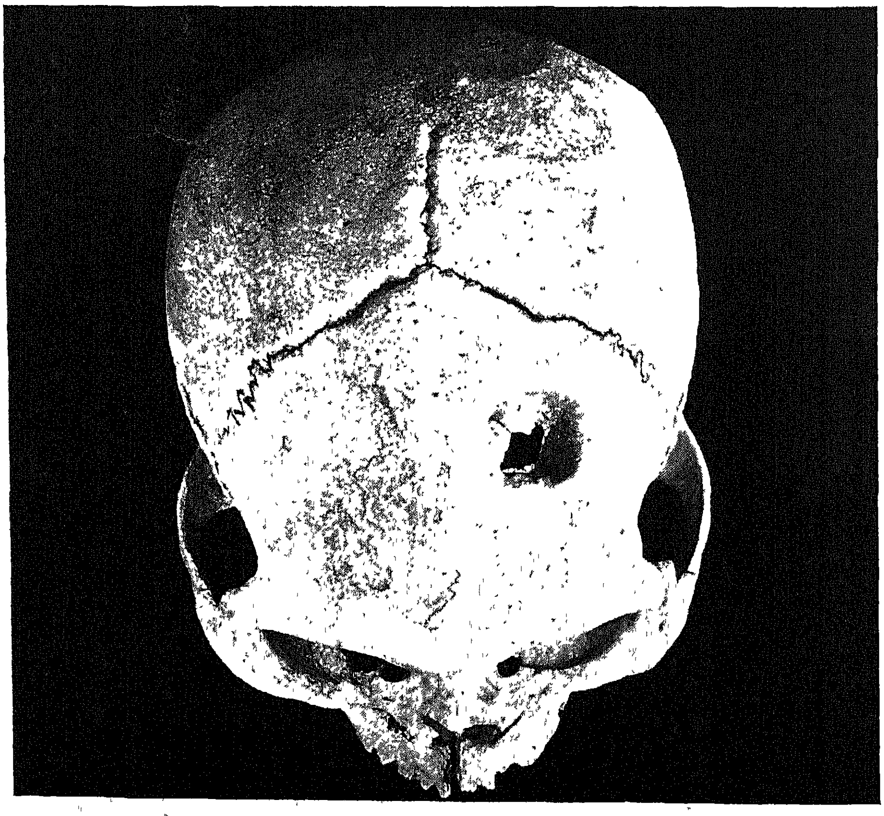
On the other hand, tuberculosis, also commonly considered an infection of civilization, definitely has an ancient history. The most famous ancient case of this disease is that of the Egyptian "Priest of Ammon," of the 21st Dynasty in 1,000 B.C., whose bones show evidence of one form of the infection known as Pott's disease, which leaves a collapsed and laterally curved backbone. Bone tuberculosis goes back much farther, however. It is reported in predynastic Egyptian times, about 5,000 B.C. At Heidelberg, in Germany, a skeleton was found from the New Stone Age with its mid-dorsal vertebrae (those at the level of the shoulder blades) collapsed and eroded as in tuberculosis.



KNOWN ANTIQUITY of human diseases and disabilities is depicted in this chart. Specific conditions are listed in the column at the left. Horizontal bars show age of evidence indicating each condition. White sections in some bars indicate age of less reliable evidence. Scale changes to the right of vertical gray bar.



HOLE IN THE SKULL of a long-dead Peruvian is evidence of the ancient practice of trephining. Some tribes performed this operation to relieve pressure caused by fracture or concussion. Since bone about hole in the picture above has not regenerated, operation probably killed patient.



PARTLY HEALED OPENING left by trephining demonstrates that patients often recovered from the operation. The Incas of Peru were the most adept practitioners of trephining. Some Inca skulls indicate that as many as four trephining operations were performed on the same individual.

In the Western Hemisphere a case of Pott's disease was found in a pre-Columbian Inca tomb, and other tuberculous backbones have been unearthed in pre-Columbian Indian mounds of Tennessee and Louisiana, and in the pueblos of the Southwest. The antiquity of tuberculosis is corroborated in ancient Egyptian, Inca and Aztec art, which often depicts the characteristic hunched backbones of victims of tuberculosis of the spine.

Man in a state of nature also suffered from deficiency diseases, although apparently these were less common than in modern populations. New Stone Age skeletons in Sweden show definite evidence of rickets, the disease usually caused by lack of Vitamin D. The German pathologist Rudolf Virchow held that the extremely curved thighbone of Neanderthal man was rachitic; he suggested also that the skull of the Java ape man of about half a million years ago was rachitic, because of its peculiarly ridged or "keeled" frontal bone.

There is even evidence of tumors among prehistoric peoples. A Swiss skeleton from the New Stone Age showed in skull, lower jawbone, chest and hands, the characteristic bone overgrowth called acromegaly, which accompanies a tumor of the pituitary gland at the base of the brain. Evidence of another type of brain tumor, called dural meningioma, was found in a pre-Columbian Inca skull. This disorder results in excessive thickening of the fibrous layer around the brain, which in turn presses against the skull, causing cranial-bone overgrowth. Still another type of bony overgrowth, in which the skeletal bones become massive and tortuously distorted, is that known as Paget's disease. It has been found in a New Stone Age skeleton in France and in a pre-Columbian "mound-builder" skeleton in Illinois. In the latter case, objects present in the mound suggested that the man buried in it may have been a person of importance—a medicine man, or possibly a priest. This would be in keeping with practices among present-day primitive peoples, who often believe that a person with a twisted body or a disturbed mentality is "possessed" and hence has special magical powers.

A STRIKING example has been found among the ancient Egyptians. There is an unusual congenital bone pathology that results in disproportionate dwarfism. In this condition, called achondroplasia, not only are the victims small, but the proportions of the head, trunk and limbs are disturbed: the head is large, with a small, concave face; the trunk is relatively long; the limbs, especially the legs, are short, with shortness most marked in the forearm and the lower leg. Achondroplastic dwarfs go back to 6,000 B.C. in Egypt. They were not treated as freaks but often actually rose to positions of power. The achondroplastic Dwarf of Zer, who lived between 4,715 and 4,658 B.C., was pictured

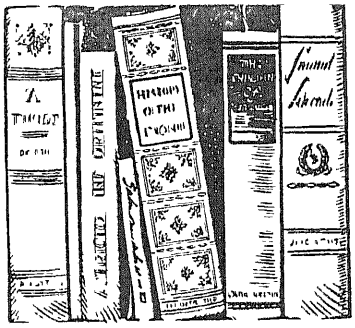
at Abydos, in Egypt, as a personage of importance. In the Fifth Dynasty of Egypt, about 2,700 B.C., lived the famous dwarf Chnoum-Hotep, often depicted in paintings or in sculpture. He was called "Chief of the Perfumes" or "Head of the Wardrobe," and was high in the favor of the reigning Pharaoh. Even pictures of the Egyptian god Bes suggest a touch of achondroplasia. This type of dwarfism is also found in the New World among pre-Columbian Indians.

Congenital abnormalities or accidents—various types of disturbed bone growth that arise during prenatal life and are present at birth—are fairly common among the remains of ancient man. Some have been found in skeletons at least 25,000 years old. Most of them show "mid-line failures"—that is, failures of perfect fusion, during prenatal development, between the right and left halves of the body. Such a failure results in incomplete formation of the bones or bony structures. Prehistoric evidence of this pathological condition is seen most frequently in cleft palate; *spina bifida, i.e.,* failure of the vertebrae to unite in a complete arch, so that the spinal cord is not enclosed in a bony canal as it should be; and "perforate sternum," *i.e.,* incomplete development of the breastbone so that it is cleft in two or has small mid-line holes. Another type of prenatal deformity, congenital clubfoot, was found in the 6,000-year-old skeletons of Egyptians. Skeletons have also been discovered with asymmetrical arms or legs, or parts of either, a condition that sometimes results from accidents or injuries at birth. In a huge cemetery in ancient Iran, dating back to 3,000 B.C., the writer found three skeletons with the right upper arm bones markedly short on one side; the circumstances of the burial hinted at a familial, and therefore possibly a hereditary, association.

The skeletal remains of course do not necessarily show the actual antiquity of a disease, but only its minimum age. Moreover, we cannot deduce from them the actual frequency of a given pathology in ancient times, for the finds of skeletons thus far are too small in number to serve as representative samples of early populations.

Nonetheless, we can be sure that the differences, if any, between the prehistoric and modern occurrence of disease are differences of degree, not of kind. Prehistoric man had virtually all the bone diseases that have been observed today or in recent times; he suffered his share of aching joints, warped and broken bones, bad teeth and skeletal abnormalities. And there was not much that he could do about it. When he was sick, he was sick. That was the end of it—and often of him!

Wilton M. Krogman is professor of physical anthropology at the University of Pennsylvania's Graduate School of Medicine.



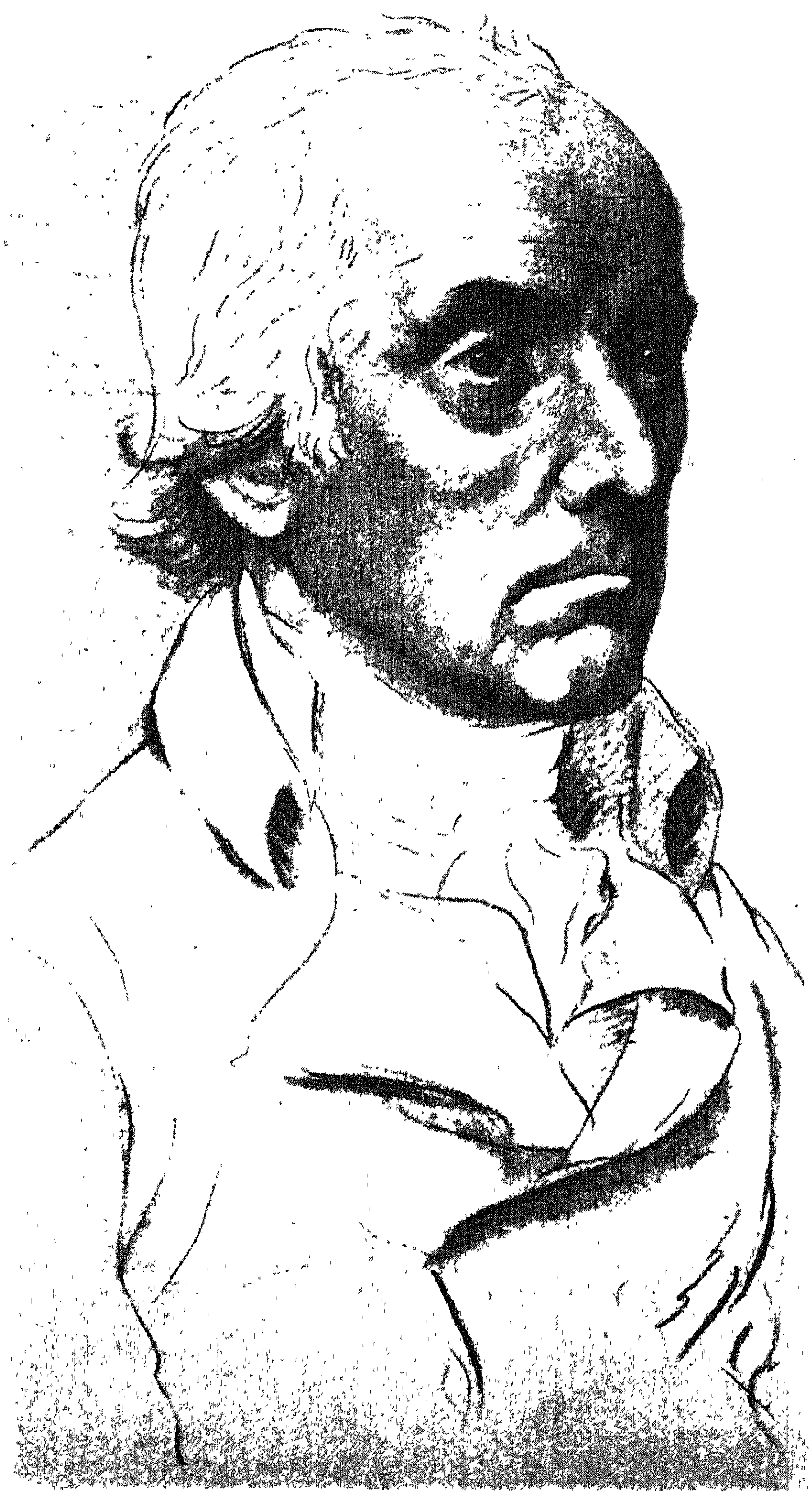
by James R. Newman

THE AUTOBIOGRAPHY OF BENJAMIN RUSH. Edited by George W. Corner. Princeton University Press ($6.00)

IN this handsome volume are gathered for the first time the journals of Benjamin Rush, physician, teacher, politician, patriot of the Revolution, and signer of the Declaration of Independence. With the aid of a grant from the American Philosophical Society, the noted embryologist George W. Corner has prepared an admirable edition of Rush's *Travels Through Life*—"a document intended for his own private satisfaction and for the edification of his family"—and of his *Commonplace Books*, a more intimate diary containing assorted but wonderfully vivid jottings drawn from his experiences between 1789 and 1813. Together these constitute the fascinating autobiography of a difficult but great man.

After a five-year apprenticeship in the "shop" of Philadelphia's leading physician John Redman, Benjamin Rush entered for his degree at Edinburgh, which had then supplanted Leyden as the foremost center of European medicine. Beginning in 1766 he spent two years attending lectures in medicine and chemistry, studying classics and mathematics under a private tutor, and enjoying a social and intellectual life which profoundly influenced his later way of thinking. For his political awakening, Rush acknowledges himself particularly indebted to a Mr. Bostock, whose father had commanded a company under Oliver Cromwell. From Bostock he first learned the "great and active truth [which] became a ferment in my mind" that "no form of government can be rational but that which is derived from the Suffrages of the people who are the subjects of it."

His formal education completed, Rush tasted for a few months the high life of London and Paris. Having as his social mentor the esteemed Dr. Franklin, in whose family he had the "peculiar happiness to be domesticated," Rush was able to meet the leading literary and political figures of both capitals. His notebooks are full of colorful details and satirical, but never humorous, observations about personages and incidents; they are particularly rich in the trivia of table conversations set down in his grave, righteous, but



BENJAMIN RUSH was a Philadelphia physician and one of the public figures of the Revolutionary period. This drawing by the contemporary artist William Haines shows much of Rush's character. He was intelligent, overworked, jealous of his theories, embittered and devoid of a sense of humor.

BOOKS

Two historical items: the life of Benjamin Rush and David Bradley's account of the Bikini tests

nevertheless charming style. His highest accolades were reserved for those who were well spoken and morally earnest like himself; profanity he detested above everything. His glimpses of the great are as pointed as they are amusing. One evening Sir Joshua Reynolds invited him to dine with Samuel Johnson, Oliver Goldsmith and several other "distinguished literary characters." Johnson was talkative and no more forbearing than usual. Of Boswell, Johnson remarked: "he was much given to asking questions and . . . they were not always of the most interesting nature. For instance he will sometimes ask 'Pray, Doctor, why is an apple round, and why is not a pear so?' " Encountering the talented Mrs. George Macaulay, author of an eight-volume history of England, Rush "took the liberty of telling her that some grammatical errors had been made by the printers of her history. She answered, 'No, they are my errors and not the printers'. I have continuously refused to have them corrected, lest it should be suspected that my history was not altogether my own.' "

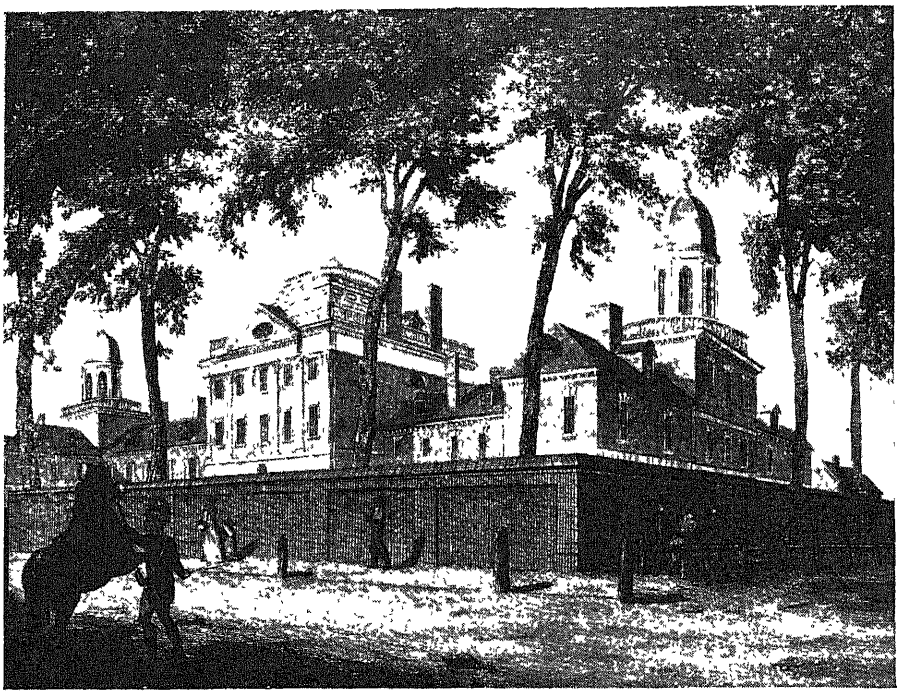
Returning to Philadelphia in 1769, Rush soon became one of the city's prominent physicians. No man ever worked harder, with less self-indulgence and more self-denial. "My shop was crowded with the poor in the morning and at meal times, and nearly every street and alley in the city was visited by me every day." Though his income was large, he was in the frequent habit of remitting fees, as egotistical as he was generous, he repeatedly calls attention to these benefactions in the journals. It is characteristic of the man, of his candor, of his curious mixture of materialism and unselfishness, to explain even in the account written for his children that he sought the poor as patients because he had "a natural sympathy with distress of every kind" and also because having "no patronage or powerful family connections . . . [this was] the only mode of succeeding in business which was left for me." He took no vacations; when he had a rare free afternoon "he took his boys to see an exhibition or visited somebody who might have useful facts to contribute."

Beginning in 1773 Rush took an increasing interest in "the controversy between Great Britain and the American colonies." Under a variety of pseudonyms he wrote political tracts in favor of independence and was soon "admitted into the confidence" of many of the early leaders, including Thomas Jefferson, John and Samuel Adams, Patrick Henry, David Rittenhouse and Tom Paine. "I waited upon nearly all the members of the first Congress, and entertained most of them at my table." As a result of his political discussions with Paine, the famous *Common Sense* made its appearance—a work for which Rush not only suggested the title but contributed advice as to content.

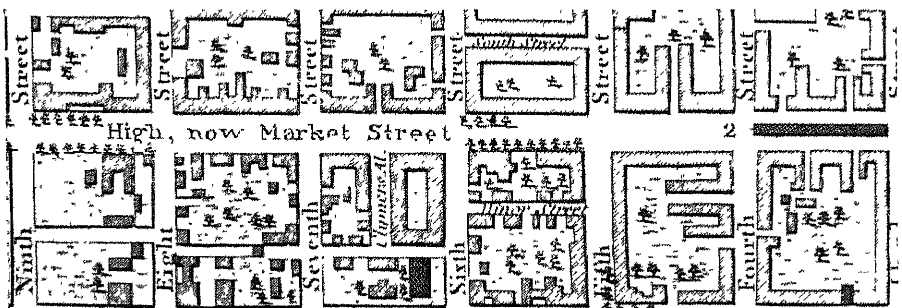
In 1776, having participated in the affairs of numerous revolutionary committees and conventions, he was designated to serve in Congress as a representative of Pennsylvania. "A few days afterwards I subscribed a copy upon parchment of the Declaration of Independence." For a time he served as "physician general" in the Continental Army. Appalled at conditions in the hospitals, he sent several letters to George Washington describing what he had seen, including the malpractices of leading officials. While his principal recommendations for reform were adopted, his vigorous denunciation embroiled him in controversy, and in 1778 he resigned his commission and returned to practice in Philadelphia.

In 1793 the city was struck by an epidemic of yellow fever. Rush drove himself unsparingly in tending the victims, but his method of treatment and the steps he devised for combatting the causes of the epidemic brought him into bitter clashes with his colleagues. "No ties of ancient School fellowship, no obligation of gratitude, no sympathy in religious or philosophical opinions, were able to resist the tide of public clamor that was excited against my practice." His medical theories provoked "torrents of abuse," especially from the pen of William Cobbett, who at the time published a Philadelphia newspaper. Rush's "business" fell off sharply and although in 1797 he was vindicated in a famous libel suit against Cobbett, irreparable harm had been done to his reputation. Overworked, embittered, jealous of his theories, incapable of self-criticism, devoid of any sense of humor, Rush found this hostility particularly hard to bear. Yet he went on, full of energy, in his work, his studies, his teaching and writing. In 1797 he was fortunately able to "supply" the diminution of his resources by accepting an appointment as Director of the U.S Mint.

From our vantage point in history it is not too easy to determine the merits of the disputes that raged over Rush's medical system. It was to William Cullen, Edinburgh's noted physiologist, that Rush owed the medical theories that originally



FIRST HOSPITAL in America was built by Rush and others at the corner of Eighth and Pine Streets in Philadelphia. The hospital is still standing. Although Rush's medical theories differed from those prevailing in his time, he made no outstanding contribution to the future practice of medicine.



MAP OF PHILADELPHIA in Rush's day shows the location of his hospital. It is at the lower left, marked with the number 15. Rush himself toured the city indefatigably in his medical practice. He sought the poor as patients because, he wrote, he had a "natural sympathy with distress of every kind."

set him apart from most of his colleagues and brought him as much of unhappiness as of fame These theories, in Corner's words, postulated "that the nervous system is the source of life, and that disease is due to failure of its regulatory powers." As far as the patient's chances of recovery were concerned, Rush's theories were neither appreciably better nor worse than the theories of Hermann Boerhaave of Holland, which they gradually supplanted. In Rush's modified system, it was held that there was only one kind of fever; that it was caused by "over-excitation," primarily of the blood vessels, and that cures could be effected by diet ("stuff a cold and starve a fever"), "heavy purging with jalop and calomel, and bleeding to the limit of tolerance"

Except for the diet feature, which could not fail to serve a useful purpose in an age when anyone who could afford it usually ate himself into a stupor every time he dined, it is incomprehensible why Rush's methods should have been any more successful during the yellow fever epidemic than those practiced by the more conservative physicians. Statistics are not available, yet the general impression is that Rush did obtain better results—a fact that was not the least of the provocations to his enemies. Of course it never occurred to him—he was, as Corner reminds us, both genius and intellectual fumbler—that a treatment "which inevitably produces general debility, to relieve excitement of blood vessels supposed to result in the first place from debility" had something quaint, not to say illogical, about it. But neither Rush nor the other 18th-century practitioners were disturbed by such contradictions; their systems throve on paradoxes, even if their patients did not.

I regret that space forbids a further sampling of the contents of these absorbing journals. Among their more striking entries are descriptions of the speculation craze and the great Script Bubble in which the members of Congress as well as humbler citizens were caught, of Philadelphia's social and political life at the turn of the century; of all manner of oddities, including a "learned pig" which cost a thousand dollars, was "½ a foot high" and showed an amazing virtuosity in the arts of counting and spelling; of John Quincy Adams' views on Prussia; of the virtues and foibles of various patriots; of Mrs. Duchés' delicate stomach. Apart from its solider merits, the autobiography is a delightful museum of curious scientific facts, anecdotes, vulgar errors, medical lore and obituaries. That the last category represents a major but lost art may be judged by comparing Rush's tart, brilliant, unhypocritical sketches with what passes for an éloge in the modern newspaper. His brief delineations of the other signers of the Declaration of Independence are masterly, if not altogether unprejudiced.

When Charles Thompson was asked to write a history of the Revolution he re-

fused, saying, "Let the world admire the supposed wisdom and valor of our great men. . . I shall not undeceive future generations." Better than anyone else could have done it, Rush has revealed himself to us as he really was. A man of extraordinary abilities, of austerity, force and courage—also a man of strange contradictions. His writings at least have not deceived "future generations." Among the sketches of the signers appears his own self-appraisal, the single line:

"Benjamin Rush. He aimed well."

No Place To Hide, by David Bradley. Little, Brown & Co ($2.00).

THIS book is the story of the atomic bomb tests at Bikini, told by a young physician assigned to the operation as a "radiological monitor." During four months spent in the Pacific, David Bradley's main tool and almost constant companion was a Geiger counter, which he used to measure the radiation aftereffects of the two explosions. Within a few minutes after each burst he flew over the targets. Later he examined ships, water, coral, algae, pigs, fish, and other items, organic and inorganic, which had been deliberately or accidentally exposed to radioactivity. His observations, personal and scientific, were recorded in a log upon which this little book is based.

The scientific information contained in *No Place To Hide* is familiar enough to those whose professional interests lie in this direction. But because the President has so far refused to release even a censored version of the report by the Joint Chiefs of Staff Evaluation Board, these and other essential facts have not been made known to the general public. In view of the disclosures of the Smyth Report and of the urgent need for dispelling gross speculations and myths about atomic weapons, this is a strange stand. One may suppose that the official policy of secrecy prevented Dr. Bradley from giving a more complete account of even his limited experience.

From a military standpoint the Bikini operation, involving 42,000 men and costing tens of millions, was something of a fizzle. It confirmed "what was already known of the effectiveness of a chain reaction as an explosive." It proved also what was already suspected, namely that when an atomic bomb is exploded in water, radioactive particles are sprayed about and spread in deadly profusion by the water's motion. Target ships in the lagoon, for example, staunchly withstood the blast waves, but radioactivity emanating from fission products left the vessels uninhabitable for months, perhaps years.

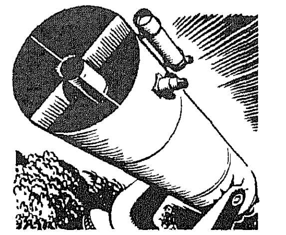
The amount of radiation produced by the explosions was enormous. One ten millionth of a gram of radium is the maximum the human body can absorb at one time without pathological consequences; the tests, as Bradley points out, released radiation equivalent to tons of radium. What this would signify if atomic bombs were used in actual combat at sea is easy to imagine. The surviving crew members would be forced to abandon ship immediately and to flee through neighboring waters more dangerous than any mine field. The inhabitants of harbor cities would also face the hazards of waterborne fission fragments, although to a lesser extent.

The military undoubtedly learned some useful facts at Bikini, especially in regard to the offensive possibilities of atomic weapons used against ports, harbors and naval vessels. The plain man, who also has a stake in the matter, remains in a condition of ignorance and anxiety. Dr Bradley's account does not, in my opinion, substantially relieve either condition.

I am inclined to think that *No Place To Hide* has been widely acclaimed for the very reason that it should be condemned. It is a sincere but misguided attempt to frighten and to horrify, with the vague hope that somehow this may do some good. What good? Dr. Bradley was apparently disturbed at finding the people of San Francisco—the first city he visited on his return—"busy and happy, well fed and well amused," uninterested in the Bikini tests. This "customary euphoria" made him uneasy. Yet how would he wish people to behave? And what constructive purpose does he seek to achieve in telling this sort of story?

It is surely obvious that the American people—all people—are deeply afraid of atomic bombs and of another war in which they may be used. Every public writing and utterance, everything that is broadcast, is designed to feed this fear. The policy of the Administration, insofar as there is a policy on this subject, is to preserve ignorance of the weapon on the ground of national security; this in turn leads to wildly mounting conjectures and to more fear. In this book, with its faint mood of approaching doom, its preoccupation with the hideous dangers of radioactivity, its total failure to place in rational perspective the realities of atomic warfare, including the feasibility and likelihood of the large-scale use of atomic bombs, Bradley does a disservice to the very cause he seeks to promote. The account imparts enough information to provoke excitement and to intensify an already widespread sense of fatalism and helplessness; it is too incomplete to contribute to clear thinking on what is admittedly a terrifying but not necessarily an insoluble problem.

It is of course unfair to criticize Bradley for not writing a wholly different kind of book; it is fair, on the other hand, to criticize him for the inevitably mischievous results of the book he has written. As an antidote to feeling sorry for ourselves, and as the first step to a saner outlook, I recommend the reading of Patrick M. S. Blackett's *Military and Political Consequences of Atomic Energy.*



THE AMATEUR

Conducted by Albert G. Ingalls

STREET lamps, houses and trees about the home of this writer keep him from engaging in one activity of amateur astronomers observing variable stars. To compensate for this shortcoming, he recently joined the American Association of Variable Star Observers (AAVSO), and observed some of the observers. Attendance at one of the twice-yearly week-end meetings, the one in the fall of the year always being held at the Harvard College Observatory, permitted a close view of this compact, efficient organization and gave answers to many questions that others have been heard to ask Just how are variable stars observed? What is the motive for this activity which, on the face of it, appears to be drudgery? Since many variable star observers work earnestly at their avocation year in and year out, it obviously must have a hidden attraction.

The attraction is the sum of a number of things. The AAVSO is mainly an amateur organization. Its members do scientific work that professional astronomers cannot because there are too few of them free to keep close watch on some 600 selected variable stars. That work is described in literature available from the AAVSO *Recorder*, Harvard College Observatory, Cambridge 38, Mass.

When a candidate applies for membership in the AAVSO (dues $3) and is elected, specific areas of the sky, usually three degrees square and containing a particular variable star, are assigned to him. He receives 10 charts showing these and the background stars, with instructions that tell him how to proceed for telescopes with or without setting circles. Telescopes of three-inch aperture or larger are suitable for this work. It happens, incidentally, that not all variable star observers make their own telescopes. They are generally satisfied with using them.

The candidate studies the charts and the corresponding areas in the sky which, after some observation, become as familiar as the back of his hand. On the charts numerous nonvariable, or constant, stars are designated with numbers that accurately indicate their magnitudes to tenths. The observer selects two of these constant stars, one a little brighter and one a little fainter than the variable, and estimates how bright the variable is in comparison with them. As an example, suitable comparison stars are marked on one chart as magnitude 8.8 and magnitude 9.2. By interpolation, the nearby variable is estimated by the observer at, say, 8.9. This is entered in a record book and each month reported to the *Recorder* on a special blank. Observations for other variables on the several charts assigned the observer are similarly recorded.

Doing this and nothing else would soon become a bore. However, as soon as the beginner has become acquainted with the fields assigned to him, he is encouraged to roam the sky and extend his observing list. He may observe any and all variables for which he has charts. On a single night, as a matter of fact, several observers may work to observe the same variable star.

Variable star observers meeting at the Harvard College Observatory

ASTRONOMER

In the course of time the variable star observer studies the sky in detail. Thus variable star observing provides a good motivation for studying the whole sky. This, many amateur astronomers find a little difficult without the guidance of a program in which other observers are involved.

Observation of the observers at a single meeting suggests several possible reasons for their year-in, year-out loyalty to the AAVSO It is a purposeful organization in which serious telescope owners may enjoy the dignity and some of the status of the professional astronomer. Some have even become professionals. An additional attraction of AAVSO membership is the scientific and social fellowship of kindred spirits. The tone of the AAVSO is dignified but not stuffy.

The members receive a great deal of individual recognition for their efforts, both from the professionals and fellow amateurs. Rising votes of thanks, with prolonged applause, pleasantly embarrass many successful observers at AAVSO meetings.

The organization is expertly run, which is another satisfaction to its members. Its business sessions are short and to the point. The scientific sessions are conducted like those of other scientific societies, even though no more than 50 AAVSO members constitute the audience The limited number of papers read, usually about 10, prevents somnolence.

The accompanying social sessions are arranged on the premise that people attend conventions mainly to talk with one another. At the conclusion on a Saturday evening of the autumn meeting there is a banquet marked by sociability and scientific pronouncements. Each year the AAVSO meets twice: once in October at Cambridge, and once in the spring in various other places.

There is a keen, friendly competition among AAVSO members. Everything that any member does in the time he can devote to observing is made known to the other members through the publication of individual observations. There is, however, a great variation in the amount of time that the members can devote to their avocation. In the year ending last September each of 24 members made 50 to 100 observations: 32 members made 100 to 200 observations, 13 members made 200 to 500 observations; 13 members made 500 to 1,000 observations; six members made 1.000 to 2,000 observations; and six members made 2,000 to 7,500 observations.

The heavyweight champions in the 2,000-to-7,500 observation group were Ahrent of Germany with 2,582 observations; Peltier of Ohio with 2.598 observations; Paletsakis of Greece with 3,473

observations; Chessapis of Greece with 3,642 observations; de Kock of South Africa with 4,729 observations; and Fernald of Maine with 7,504 observations.

These six crack observers really work at their job. Together they account for 45 per cent of the year's grand total of 54,370 observations. These are made by 154 observers in 18 nations, of whom the U. S. has 105. Greece is second with 11.

In the photograph on page 60, Cyrus F. Fernald of Maine, the champion variable star observer, stands in the center with hands crossed. The second man at his right, wearing a checked tie, is Leon Campbell of the Harvard College Observatory, the AAVSO's Recorder, one of its organizers, and for more than 30 years its activator The man second from Dr Campbell's right, wearing a dark suit, is Harlow Shapley, director of the Harvard College Observatory. In recent years Dr. Campbell has also been responsible for the actual promotion of work among active AAVSO members. In the rear center shows your scribe's left ear—an appropriate representation for a listening, lowly, non-observing freshman member

In addition to variable star observing, the AAVSO sponsors the organized observation of the occultation of stars by the moon, and the systematic observation of sunspots. It also maintains a nightly watch of the sky for the sudden appearance of a bright nova.

Cyrus Fernald writes: "The companionship with the other observers and with the staff of the Harvard College Observatory, not to mention other observatories, combined with the sense of satisfaction that comes from the knowledge that one's observations are doing some good, is a rich reward for the time and effort that is put into the work.

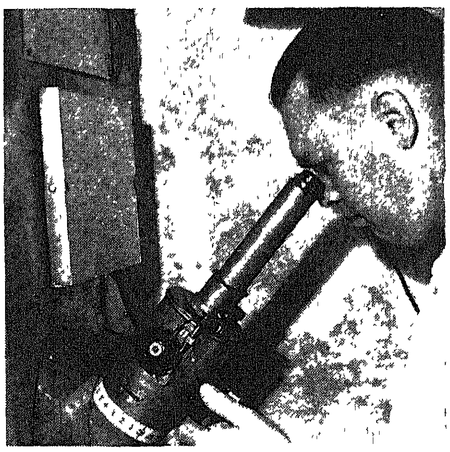
"I am," he continues, "one of those who made telescopes from the instructions in *Amateur Telescope Making* and *Amateur Telescope Making—Advanced.* From my 16 years' experience with it I am thoroughly sold on the Springfield mounting. My ideal would be an 8- to 10-inch telescope of about 70- to 80-inch focal length, with electric drive and slip ring R. A circle."

In the photograph at the right Chester Brown of 1117 Fourteenth St., Spokane, Wash, an active member of the Spokane Amateur Astronomers, may be seen sitting indoors examining the sky through a refracting telescope that points downward through a hole in the wall. This is possible because there is below the telescope a flat mirror (*see drawing at top of opposite page*) which reflects the rays from the particular part of the sky toward which it is turned. The rays then pass upward into a lens. The telescope itself is permanently fixed in position, though it can rotate on its own lengthwise axis.

Since the observer is sitting indoors, he cannot find objects simply by looking at the sky. Instead he works most accurately by an indirect method. The control mechanism of the auxiliary flat mirror is equipped with a graduated setting circle, and turns on an axis. The telescope, too, may be rotated, turning the mirror with it in a direction at right angles to the first motion; this direction is measured by a circle marked in degrees. From the astronomer's *Ephemeris* the observer ascertains the coordinates of his star, quickly sets the mirror in both directions, and the star appears in the center of the eyepiece.

Like all good things, indoor telescopes of whatever type have minor drawbacks, but one point outweighs them all. This is plain comfort. In the photograph Brown sits serenely in his shirt sleeves. Outdoors in Spokane, it has been 30 degrees below zero, but Brown has not had to slap his hands to keep them warm It has also been 108 degrees above zero, at which time he has not had to slap mosquitoes.

The indoor telescope is not, however, a suitable type for the beginner's first instrument. It might well be the second. The beginner should put in his apprenticeship outdoors on the conventional frost- and mosquito-bite telescope, and learn the sky as a whole. It is said that, due largely to



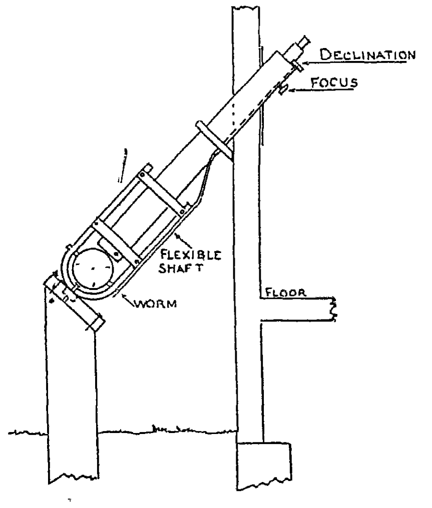
Chester Brown and polar telescope

their use of the convenient setting circles, some professional astronomers have never learned the constellations as thoroughly as some amateurs who do not use them.

J. M. Holeman of Richland, Wash., who made the accompanying photographs, also coated the lenses and aluminized the flat mirror of Brown's telescope. Holeman has furnished some details concerning the telescope; Brown has furnished others. It is of the Grubb-Gerrish type described in Bell's *The Telescope* and in *Amateur Telescope Making.* The objective lens and barrel are parts of a 4½-inch Bardou refractor of good quality. Brown made the flat from a 6-inch Pyrex blank.

Shown in the photograph are some accessories for finding stars rapidly. A wrist watch adjusted to sidereal time hangs above the telescope. Beside it is a chart to convert the positions of certain well-known stars to hour angle for adjusting the setting circles in order to begin the

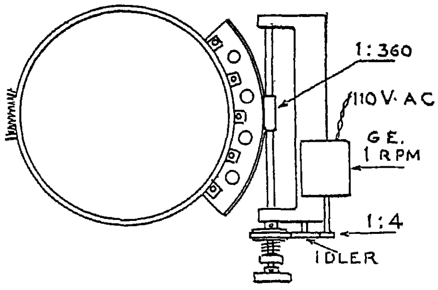
night's observing. Below this is a shallow chart box with a ground-glass cover, containing, for illumination, two six-volt radio lamps that run on current from a transformer. The charts of the heavens are placed on the face of the ground glass. This could be done, for example, with the special charts of the AAVSO. Since these are drawn inverted, and reversed for use with refractors, most observers who own reflectors use them with a mirror. Brown's telescope already has a mirror below its objective lens, which inverts but does not reverse the image of the sky. Hence he



Elevation of the polar telescope

inserts the charts in the box face down, so that when he looks through the charts from the back they correspond to what he sees.

The hour scale or right-ascension (celestial longitude) circle, visible as a white belt around the barrel of the telescope tube, is held in place by a tension spring (*see drawing below*), but may be loosened to slide it around the telescope and correspond to the date of observation. Thereafter it is driven with the telescope by a 110-volt clock motor of one r.p.m., which shows above the observer's thumb in the photograph. Other parts such as worm and segment gears were taken from a war-surplus gyropilot which cost $5.



Polar telescope drive and controls

The flat mirror is tilted in its yoke by means of a worm-driven flexible shaft or cable; its black knob is seen atop the tube of the telescope. This cable passes through the inside of the tube, emerging through a hole halfway down and, with a worm on its lower end, actuates a worm wheel identical with the one at the top. The control knob is geared, through an attached gear train and worm, to a declination circle on the left side of the telescope. Brown has many telescopes, but likes this one best because of its indoor observation feature.

The drawing, made by Russell Porter after a rough sketch by Brown, shows the tube and, around its lower part, the yoke that is integral with it. Both are rotated 90 degrees; this is to say, the declination control and focusing screw are not in the same positions as in the photograph. The pivoted thrust-bearing below the yoke fits into a hole in a wooden cap on the post. After the telescope was adjusted parallel with the earth's axis this cap was nailed to the post. The yoke is made of one-inch pipe and the telescope is attached to it with strap-iron clamps. The upper bearing of the telescope, just outside the house, is an aircraft-type ring bearing.

THROUGHOUT much of the literature of telescope mirror-making the terms parabola and paraboloid are used interchangeably as if the two were synonymous. Of course nearly everybody understands what is meant, a paraboloid being the two-dimensional surface generated when the one-dimensional curve called a parabola is rotated about its axis. The escape from the alleged crime is that when a mirror is called a parabola its cross section is described.

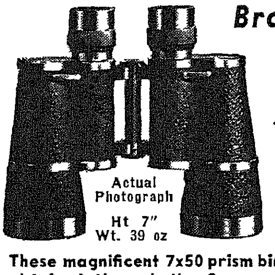
What more rightfully rubs the mathematician's whiskers backward is calling the paraboloid a curve. Being two-dimensional, it is a surface. In sum, then:

Parabola: one-dimensional, curve.
Paraboloid: two-dimensional, surface.

WALKDEN of London mentions a wrinkle for observing with his richest-field telescope. In an ordinary straight view where the telescope tube is fixed, as on a mounting, the central 20 degrees of the field may be good and the margins fairly good, until you swivel your eye to get a direct look at them with the central part of the retina. Then they seem strangely dim and also have poor definition.

What you have done, Walkden points out, is to move the crystalline lens of the eye sidewise from the Ramsden circle so only a crescent of the lens and the telescope mirror remain in use. This is because the Ramsden circle is so close to the size of the eye lens: you carefully planned it that way when you designed the telescope.

The wrinkle is simply to compensate this partial eclipse by moving the whole head in the opposite direction an amount which will come to about a seventh of an inch. If the telescope is not on a mounting it can itself be moved a little. The chances are that the average observer does these things unconsciously, but it is still instructive to realize just what he is doing and why.



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SCIENTIFIC AMERICAN

TEMPERATURE AND LIFE

FIFTY CENTS

February 1949

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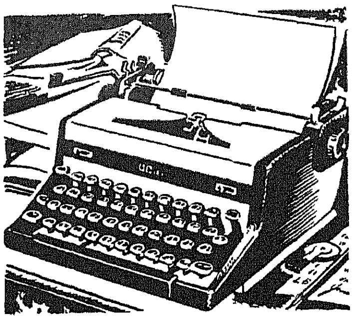

Sirs:

The public opinion polling business is a brickbat and bouquet affair. This happens to be brickbat time. In 13 years polling methods have improved considerably and no poll director in his right mind would assume that they can't be improved further. We are always open to suggestions and criticism.

But it seems to me that the article on "Public Opinion Polls" in your December issue seriously misled your readers by conveying the idea that certain sampling procedures, if adopted by the polls, would be a cure-all for the errors made in election predictions. The procedures referred to in that article failed to stand up any better than other methods under the test of the Truman-Dewey election.

The author of your December article says without qualification that area, or "probability," sampling is more accurate than quota sampling. I am not attacking or defending either method here. My concern is that your readers were not told the *whole* story. On the basis of all the facts it would seem to me unscientific to conclude that the polls in 1948 would have come out all right if they had only followed the procedures which your author champions so briskly.

It happens that area sampling *was* used in the 1948 election (though one would never guess it from the article). Competent research men used it in two areas—the city of Elmira, N. Y., and the state of Washington. The results hardly substantiate any conclusion that this procedure is better for election forecasting than any other.

In the Elmira poll the error in the Dewey figure was 6 percentage points, and in Washington the Dewey vote was overpredicted by 3 percentage points. Taken together, the error on Dewey was approximately the same, in terms of percentage-point deviation from the election result, as in the case of quota samples. It is unfortunate that your December article neglected to report this evidence which was known to all public opinion researchers.

Again, the author cites evidence from various of his own surveys to prove that area sampling produces figures that square almost exactly with census data. But I looked in vain for any mention of a famous study in which both area and quota sampling methods were used and in which the area sampling methods employed by this same author produced a sample containing 18.2 per cent of persons with college training. The U. S. Census estimate, as of April, 1947, for this same group was about 12 per cent.

Let me repeat that I am not defending one method against the other. In terms of the 1948 election the most that can be said, it seems to me, is that one method was no worse than the other. It may be that area sampling—with certain improvements which our organization is now evolving—*will* prove in the future to be the best way of forecasting elections. The only scientific way is to keep testing all methods that look promising. I would want to see this one tested some more before jumping to conclusions.

From a research point of view, one of the greatest hazards in election forecasting is the problem of identifying those persons who will take the trouble to vote and those who will stay at home on election day. Your author calls this a "knotty" problem and then goes on to say that "pollsters have made few attempts to develop questions to measure the intensity of the determination to vote." As a matter of fact, no other department of polling has been the subject of such intensive research.

Literally hundreds of experiments have been tried. One reason why this research has not been more productive is that voting is not merely a matter of

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have little interest in an election actually cast votes simply because party workers make it their business to get many of these persons to the polls! And not until someone discovers a way of measuring party-worker efficiency is there much hope of overcoming this problem.

The article also goes into the question of polls on issues of the day. The author quite rightly stresses the importance of the meaning that words used in poll questions convey to the people interviewed. This has been one field in which we of the American Institute of Public Opinion feel that we have made some very basic contributions. Many years ago we developed the "split ballot" technique to provide a means of testing the wording of questions. By conducting simultaneous polls on questions worded in two different ways, we have been able to test the effect of semantics in public opinion polling. Of all this experimenting the article takes no notice.

It also fails to report the work done by our organization in developing its "Quintamensional Plan of Question Design." This approach to complex issues of an economic, social and political character assures the polling organization of being certain the person interviewed knows something about the issue, it can ascertain the level of his information and correlate the degree of knowledge with opinion.

Finally, the article expresses concern over the fact that the results of two questions reported at approximately the same time by two different polling organizations showed a difference of some 14 percentage points. I believe a little thought will show that these two particular questions were not at all the same in meaning. Anyone in the polling field would be greatly disturbed if the public didn't react differently to different ideas.

During the next few months there will be many city and state elections in which research men can seize the opportunity to demonstrate how better forecasts can be made. This will give them the chance to try out their own ideas publicly—with, of course, the attendant risk.

When better polling techniques are developed, you can be sure that we and the other polling organizations will adopt them in a hurry. Why shouldn't we? The prestige of pollsters and in fact the very existence of polls are dependent on accuracy.

GEORGE GALLUP

Director
American Institute of Public Opinion
New York, N. Y.

Sirs:

Rensis Likert's article on the election polls in your December issue repeats the criticisms which have been most commonly made by other psychologists and polling students. These criticisms are: first, the inadequacy of the sampling, and second, the inadequacy of the methods used. May I call attention to a very obvious oversight in such criticisms?

The last Gallup Poll was made from ten days to two weeks before election day, and the last Crossley Poll from two to three weeks before the election. The last *Fortune* Poll was made by Elmo Roper three months before the election. In other words, these polls were not made during what is now conceded to have been the most critical days of the election campaign, when the slight trend toward Truman already shown by the polls may have been turning into something of a landslide

In any case, no analysis of the sample or of the method can now possibly prove that the Gallup Poll was wrong as of the time the poll was taken; or that the Crossley Poll was wrong as of the time it was taken; or even that Roper's Poll was wrong as of the time it was taken. This is a very simple and definite problem in validation, the actual election results being the criterion. Naturally, since the election did not take place at the time the other polls were made, the only thing that analysis of the polls can show now is that their prediction, or the projection of their results to a period two weeks or more later, was wrong.

Looking at this in another way, let us assume that the polls made by Gallup and Crossley had used the most perfect possible samples and the most perfect possible methods. If, in the two or three weeks preceding the election, while no polls were being made, a sharp swing toward Truman was taking place, then these ideally perfect polls would also have been wrong.

It seems to me that a great danger in respect to the election polls and other surveys is the tendency to submerge the obvious in a mass of technicalities. Techniques are, of course, important and should be continuously improved, but more elaborate and more adequate techniques are no substitute for logical analysis and judgment.

It is as simple as this: Not even the most perfect sampling methods can measure a trend if the poll using the sample is not being made. The most obvious failure of the recent election polls is that they were not made during a time when they should have been made. This error grew out of an unwarranted assumption that voters are not likely to change their minds during an election campaign, especially in the last week or two before the election.

HENRY C. LINK

Vice President
The Psychological Corporation
New York, N. Y.

50 AND 100 YEARS AGO

FEBRUARY 1899. "Divers statisticians are telling us that the world's population is growing so fast that in a few centuries there will not be food enough to support it. A Belgian statistician, Gen. Brialmont, thinks this time will come in less than four hundred years. In *Cosmos*, Dr. Albert Battandier reviews the Belgian general's arguments and concludes that there is not so much to fear, after all, but it cannot be said that he is very reassuring, for he merely puts off the evil day and then tells us to trust in Providence."

"The year 1898 was an important period in the history of space-telegraphy, it was the period in which the possibility of being able to signal across wide stretches of open sea with certainty in all weathers and at high speeds, became first generally recognized and practicable. It is very generally admitted that space-telegraphy will replace metallic circuit systems only under conditions where metallic circuits are impracticable. Space-telegraphy is at present limited to comparatively short distances and its usefulness is confined to spanning estuaries, skirting seaboards, and such purposes."

"One year ago a company put thirteen horseless electric cabs for hire on the streets of New York. To-day the same company operates one hundred cabs and they are so popular that they have to be taken from the public cab stands and kept in the cab house to fill telephone and messenger orders of regular customers. Three hundred cabs are needed to fill the demand, and it is doubtful if the demand would be supplied. In addition to the cabs there are at least thirty delivery wagons, pleasure vehicles, etc., in Manhattan proper."

"M. Lockroy, the French Minister of the Marine, has communicated to the press the fact that the new submarine torpedo boat 'Gustav Zede' succeeded in torpedoing with a dummy torpedo the French battleship 'Magenta.' "

"In spite of all failures, in spite of numerous mishaps, many minds are still endeavoring, theoretically or practically, to solve the problem of artificial flight. The dirigible balloon and the flying-machine are contrivances which, to a certain extent, supplement each other Both methods of flying are still in a state of development, but the time has passed when all attempts at flying are sneered at and derided. In the last few decades the art of flying has developed so prodigiously and has made such astonishing progress, that at no distant day the practical solution of the problem may be expected. The German government has taken such interest in the matter of aerial navigation that it has appropriated $200,000 for experiments with the dirigible air-ships of Count von Zeppelin."

FEBRUARY 1849 "There are various theories regarding the precise character of light. By some it is described 'as very minute particles thrown off in all directions with immense velocity from luminous bodies.' Others consider it as the effect of an undulation produced by luminous bodies in the elastic medium of the atmosphere, and producing an effect upon our organs of sight like sound on the air by vibrations of the atmosphere. Our opinion is in favor of the two theories combined, namely, that light is thrown off luminous bodies in all directions with great velocity and by a vibration."

"The present age is Augustan in respect to mighty achievements in science and art. Not only are works projected now that are more grand and imposing than the greatest works of Egypt, Greece or Rome, but we seem to construct works in a day, that would have required a century of ancient labor. Let them boast of ancient art who may—of ancient architecture, sculpture and painting—these are the signs of luxury and refinement and are not concomitants nor the signs of any nation's happiness or prosperity. A spinning jenny does more good to a country than a palace, and a steam engine confers more benefit than a temple."

"A memorial was presented to the Senate on Monday the 27th ult., asking for an appropriation for the construction of a telegraph from Nova Scotia to the coast of Ireland on the submerged table land which was stated to have been discovered to exist between the two continents. The memorialists propose to enclose the telegraph wires in cork tubes and anchor them at ten miles apart This proposition is as feasible as going to California in a bag of hydrogen gas."

"It is calculated that a railroad from the Junction of the Nebraska and Missouri rivers to San Francisco would be no more than 1600 miles long and that it might be constructed for the sum of $20,000,000."

"Since our government took possession of California the necessity of opening up a channel of easy communication between it and the old States has become obvious to all. The Isthmus of Tehuantepec belongs to Mexico, but we believe that government is willing to grant the right of way to the United States. By having a Railroad through Tehuantepec to the Pacific, we may expect that without any more war, a State would be formed in the heart of Mexico that would in twenty years petition to be admitted into the Union."

"According to the St. Louis Union, the total number of steamboats which have met with disaster on the Western Rivers during the past year is 109. Of this number 59 were totally lost. By the various accidents 205 lives were lost. No estimate is attempted of the loss of property. On 14 of the boats $118,800 were insured."

"The following 'Act to Protect Apprentices and Operatives in Manufactories,' is now before our Legislature. No child shall be employed in any manufactory or workshop within this State [New York] who shall not have attained the full age of ten years, and be able to read and write. No child shall under any circumstances labor more than ten hours in any one day."

"Towns and villages spring up in the western wilds 'as suddenly as the flowers of the tropics.' It is but recently that we recorded a cession of a tract of land in Wisconsin to our government by the Menominee Indians, and yet, since the conclusion of that treaty, the country between the Fox and Wisconsin rivers, which forms a portion of the territory, has been settled with emigrants, and Yankee log cabins dot the fair expanse of that delightful region where before there was nothing but the wigwam of the red man."

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THE COVER

The painting on the cover shows an imaginary scene in Yellowstone National Park, where life can be studied in extreme environments of both heat and cold (*see page 46*). The collecting bottle, watch glass and thermometer are part of the equipment used in such investigations. The mountains in the background are the home of organisms equipped to survive extreme cold. The hot pools in the foreground contain many forms of life, including the two insects shown in the painting. In the bottle is a water beetle, *Tropisternus californicus*, which is found in pools from 90 to 100 degrees F. On the tip of the thermometer is a horsefly named *Tabanus punctifer* which can live in water at some 90 degrees.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Credits
11	Edward Burks
12-13	Hal Fiedler
15	K. Chester (*top*), Edward Burks (*bottom*)
16-21	Hal Fiedler
23-25	Eric Mose
27	General Electric Company
30	Perry R. Stout, University of California
32	Eric Mose
33	George A. Boyd and Agnes I. Williams, University of Rochester Atomic Energy Project (*top*); K. G. Scott, D. J. Axelrod, J. Crowley and J. G. Hamilton (*bottom*)
34-37	Eric Mose
38-39	Eric Schaal
41	Charles Nelson, Westinghouse Electric Corporation
43	U. S. Air Force
44-45	Harvard Seismograph Station
46	Margery J. Milne
48-49	Adolf Brotman
50-51	American Museum of Natural History
52	Museum of Modern Art Film Library (*top*), American Museum of Natural History (*bottom*)
55	American Museum of Natural History
56	William Auerbach-Levy
60-62	Russell W. Porter

SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR FEBRUARY 1949 VOLUME 180, NUMBER 2

ARTICLES

DEPARTMENTS

FEAR

can be fatal

Thousands of women die every year because they are *afraid to find out* if they have cancer.

That fear is fatal . . . because *cancer can be cured if treated early.*

That's why it's so desperately important for you to train yourself to watch for symptoms, and to act immediately.

Pain is seldom an early symptom, but here are danger signals you should look for:

1. Any sore that doesn't heal.
2. Any lump or thickening in the breast or elsewhere.
3. Any change in a wart or mole.
4. Persistent hoarseness or cough.
5. Persistent indigestion or difficulty in swallowing.
6. Unusual bleeding or discharge.
7. Any change in bowel habits.

Don't let fear . . . or carelessness . . . rob you of your chances of cure.

Go to your doctor if any of these symptoms is present, or to your nearest Cancer Detection Center. You can find out where it is from the American Cancer Society, 47 Beaver St., New York, N. Y.

American Cancer Society, Inc.

CANCER *can be cured... if treated soon enough*

SCIENTIFIC AMERICAN

FEBRUARY 1949 VOL. 180, NO. 2

THE OFFICE OF NAVAL RESEARCH

It has pioneered so fruitfully in the support of basic science that it stands as a model for the planned National Science Foundation

by John E. Pfeiffer

BUILDING T-3, a gray unit in Navy Row on Constitution Avenue in Washington, is one of those "temporary" wartime structures that will probably be in use for another generation or so. It houses a young project that will last a good deal longer. T-3 is the headquarters of the Office of Naval Research, which is primarily military but also represents the first peacetime venture by the U. S. Government into the large-scale support of basic work in science. As such, it will undoubtedly serve in some respects as a model for the prospective National Science Foundation.

ONR today is the principal supporter of fundamental research by U. S. scientists Entirely aside from its own military research, in which it employs more than 1,000 scientists at three naval laboratories and six branch offices, ONR is sponsoring a huge university program. Its 1,131 projects with workers at more than 200 institutions account for nearly 40 per cent of the nation's total expenditure in pure science. These contracts aggregate $43 million—more than the entire national expenditure on basic research before the war. Of these funds, $20 million comes from ONR itself, $9

ONR'S DIRECTORS meet in weekly Tuesday morning session to consider strategy and projects in its huge program of research. At the head of table is the Office's Deputy and Assistant Chief, Captain Calvin M. Bolster.

million is distributed by ONR for other Federal agencies (principally the Atomic Energy Commission, with which it has a cooperative program), and approximately $14 million is contributed by universities. All of this money is spent in projects chosen and supervised by ONR. Thus a very substantial proportion of U. S. scientists in a wide variety of fields, from astronomy to genetics, are working for the Navy.

The Navy has managed to keep them surprisingly well contented. When ONR started operations three years ago, scientists viewed the tempting contracts it proffered with deep suspicion. They expected that accepting the Navy's money would involve them in stifling red tape, endless discussions with officers lacking in understanding of science, and endless military demands. It turned out otherwise. Many a scientist who vowed at the end of the war that he would never again work for the Government is now working happily for ONR. The Office is so well regarded by the scientific community that it receives four times as many applications for projects as it can finance.

The ONR set-up is far from Utopian, but those who are concerned with organizing the proposed National Science Foundation are examining its methods of operation as an object lesson in Government support of science with a minimum of bureaucracy. The Foundation probably will be considerably closer in operation to ONR than to the wartime Office of Scientific Research and Development, which, though a civilian agency, was concerned only with applied and military research.

MUCH of ONR's success is attributed to its sound basic organization. The Office is run by two naval officers: Rear Admiral Thorvald A. Solberg, Chief of Naval Research, and Captain Calvin M. Bolster, Assistant Chief. But they share control and policy-making with a civilian, Alan T. Waterman, a former Yale University physicist who was a leading official in OSRD during the war and is now chief scientist of ONR. In the selection of university projects to be supported, this triumvirate is assisted by an over-all naval research advisory committee and by 12 advisory panels of scientists, consisting of about 125 leaders in U. S. science. ONR itself has a headquarters staff of scientists who keep in close and sympathetic touch with the university projects.

A second reason for the program's success is that ONR has made good its promise to grant the contracting scientists a maximum of freedom. The Office has operated on the sound assumption that the laboratory worker in basic science hates administrative detail, wants complete freedom of action and publication, and generally is utterly unconcerned about the application of his findings (although ONR officers have observed that he is as gratified as anyone else when others put his work to use).

When a scientist submits a project for ONR support, he is given no blanks to fill out but is asked only to describe his project clearly, list the expenses and needed equipment, and supply other necessary details. After the contract is signed, he is spared any fiscal paper work. The contract is made with his university, and the university administrative office handles the bookkeeping. The scientist is expected to make a progress report every three months, and a final report on completion of his work. Although he is encouraged to publish his work in scientific journals, he is not pressed to break into print at periodic intervals—a convention which has been a long-standing grievance of scientists working under grants from private foundations.

Like any agency spending the taxpayers' money, ONR has not found it easy to get over the habit of demanding an accounting for every penny and every minute. The armed forces, accustomed to buying chiefly "hardware" to be delivered in definite quantities at definite times and places, at first had a tendency to regard the findings and ideas of research in the same way. They sometimes went to the extreme of insisting on technical reports of a predetermined number of double-spaced, typewritten pages. While ONR has never required its scientist-contractors to punch time clocks (as some laboratories did during the war), it made some attempts to obtain weekly reports of time worked. It was cured of this fault early, notably by a Northwest-

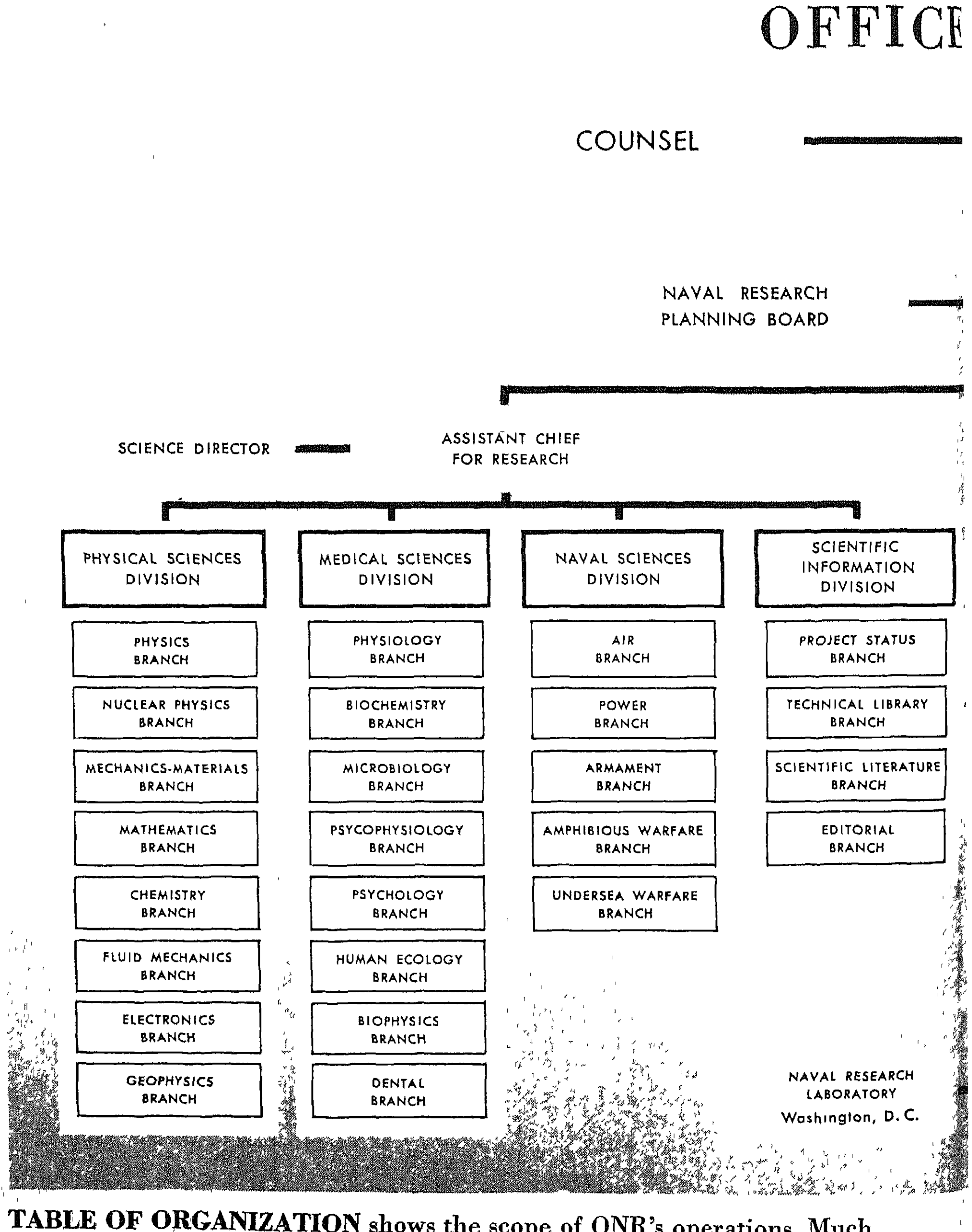


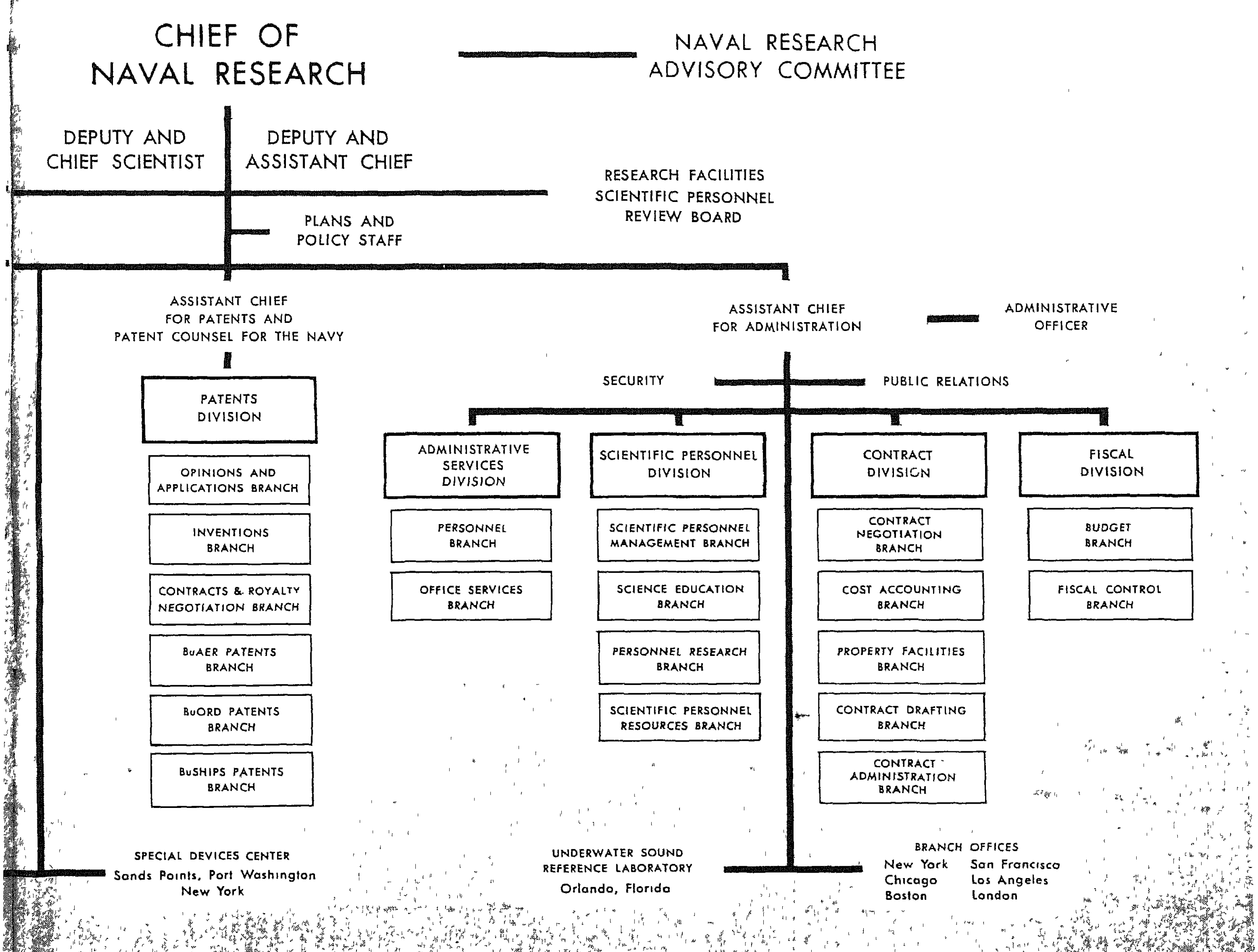
TABLE OF ORGANIZATION shows the scope of ONR's operations. Much scientific work is carried on by men who are employed full-time by ONR.

ern University psychologist who was conducting experiments in intelligence testing, and who in mid-contract was requested by a Navy representative to keep track of the time spent on the project by the graduate students helping him. The psychologist complied, and a few weeks later crisply informed ONR headquarters that his assistants, now spending exactly the time they were required to, were working 50 per cent less time than they had previously worked at the same pay. ONR now requires only a monthly report, filled out by an administrative clerk and signed by the project supervisor.

MOST surprising of all has been ONR's ardent and unflagging fidelity to the principle of supporting research of the most fundamental nature—a principle which was laid down more than three years ago by Vice Admiral Harold G. Bowen, who fathered ONR and became its first chief. ONR is financing at least half a dozen studies in low-temperature physics, an inquiry which before the war was a monopoly of European scientists It is supporting a Princeton University study of "The Mathematical Structure of American-Type Economics" Its projects include investigations of cosmic rays, meteors, white dwarf stars, viruses, the structure of protein, the biochemistry of muscle and nerve. It is partially financing the construction of 15 cyclotrons, synchrotrons and other accelerators. It has even disregarded service rivalries and assisted entomologist Theodore Schneirla's interesting studies of the army ant.

Many of its projects, of course, are likely to lead to more immediate naval applications. One study with fascinating possibilities is a psychological analysis of 18 Navy captains who distinguished themselves in combat during the war, to the end of determining what qualities make an outstanding military leader. ONR is assisting in the construction of a high-speed electronic calculating machine that is expected to multiply 40,000 10-digit numbers per second. At Princeton it is supporting a study in statistics designed to yield methods for drawing conclusions from intensive examination of very small samples, e g., as few as five or ten observations. A typical application of such a technique would be in the investigation of methods for diagnosing cancer, where the number of patients available for study of a particular chemical clue may be very small.

OF NAVAL RESEARCH



Of principal interest, however, is ONR's policy of support of basic research, which has done much to bridge the period between the war's end and the anticipated establishment of a National Science Foundation.

Such work is under way at Memorial Hospital in New York City. In a similar project, at the University of Pennsylvania, the role of economic and occupational factors in the speed of the disease process in tuberculosis is being studied.

What does the Navy hope to get out of all this? Admiral Solberg, ONR's chief, insists that the advancement of naval warfare rests ultimately upon the findings of up to the minute basic research. A practical man, Solberg was formerly head of the Naval Boiler Laboratory in Philadelphia and an engine-room officer at sea; he also had charge of the assessment of damage to the warships in the Bikini atomic bomb tests. The basic science projects supported by ONR, he explains, all come under the head of what the Navy calls "supporting" research, which means that they are chosen to fill needs for knowledge considered essential to national security in general and to naval interests in particular. They are selected as far as possible on the basis of their bearing on problems of specific concern to the Chief of Naval Operations and the various bureaus of the Navy. When a report is rendered to ONR on the results of a project, significant findings are passed along to naval laboratories and other interested service agencies, where they may be put to use in practical design problems Findings in physical science are reported to naval engineers, biological data to naval physicians and surgeons The results of psychological and sociological studies are applied to problems of human engineering, training, personnel selection and leadership.

To achieve a more accurate selection of pertinent projects, ONR is now developing a section devoted to "program research." This section is analyzing Navy objectives with a view to uncovering gaps, weak spots or critical areas where research is needed. For example, naval tacticians may pose such a problem as this A large task force of many carriers and aircraft is attacking a small, well-defended military zone under conditions of zero-zero visibility. What new weapons and devices, and hence what basic research, would be needed to increase significantly the chances of destroying the target? ONR has already drafted several research programs which are based on such practical problems as these.

For obvious reasons, ONR, while willing to disclose many of the individual projects for which it has contracted, will not permit publication of the entire program.

As far as the scientists are concerned, ONR's system imposes no hampering directives. The research program is "directed" only in the sense that ONR selects projects which it considers to be pertinent to its own plans. For the most part the projects are proposed by the scientists themselves. Their work follows the lines of their own interests and inclinations; if their basic studies are deemed of value to the Navy they obtain support which often would be unavailable from any other source. Few of the scientists who work under ONR contracts express any particular concern about the fact that their work may advance military technology. They consider that the source of funds is relatively incidental. They are doing exactly what they want to do under conditions of complete scientific freedom, and the basic contributions they are making to scientific knowledge have their own value, not restricted to possible uses by the Navy.

Obviously the scope of ONR's support of fundamental work depends on the breadth of its interpretation of what may be useful to the Navy. So far this interpretation has been liberal, as is indicated by the sample projects already mentioned. Yet there are limitations—limitations that not only underline the need for the speedy establishment of a National Science Foundation but suggest some lessons that such an agency might be able to learn from ONR's pioneering experience.

One lesson is that the achievement of a balanced program of research cannot safely be left to the unregulated processes of supply and demand. Of ONR's basic-science budget, more than 75 per cent has been spent in the physical sciences and only 15 per cent in the biological and medical sciences. (The remaining 10 per cent or so has been allotted to naval sciences.) The value of research in nuclear physics is more obvious to the Navy (and to civilian agencies, one may note) than is the value of research in the life sciences. The Navy also argues that medical research is being supported by many other agencies. In any case the one to five ratio of biological to physical science that has developed in the ONR program is far below the one to two ratio suggested by Vannevar Bush of OSRD in his proposal for a science foundation to President Truman. Biologists also point out that the U.S.S.R., which cannot be accused of diverting funds to impractical research, has undertaken to expand its biological research program rapidly since the end of the war.

Another reason for ONR's relatively small support of biology may be the failure of the biologists to press their case in an organized way. Engineers, chemists and physicists have promoted their professional interests through active, long-established national organizations. The biologists, realizing their handicap, a year ago formed the American Institute of Biological Sciences, but the organization has shown little sign of life. Its inactivity may account for the fact that ONR's 13-man advisory committee has only two biologists.

Perhaps the most serious weakness in the ONR system of support has been the short duration of its contracts. They average just under a year and a half—far too short a period to give scientists the degree of security they need in basic research, where results do not come overnight. Moreover, under the ONR plan a scientist may run out of funds just when the work is becoming most interesting to him. His mission for the Navy presumably is accomplished when he has delivered certain desired information. But the research may have opened an unexpected new line of inquiry which intrigues him even more than the original project Because the Navy cannot be expected to continue to support the pursuit of pure knowledge beyond its own limited aims, the scientist must either give up the inquiry or start a new hunt for funds from another source.

All of these problems are now being intensified by a shrinkage in ONR funds. Its allowance depends not only on the size of the nation's military budget but also on the competitive demands of other military agencies upon that budget President Truman's budget for the coming year allows $530 million for military research and development. This is divided up among the Army, Navy and Air Force; and of the Navy's allotment, the lion's share then goes for "development," meaning engineering and test production of devices. What is left goes into basic research. Because of other demands on ONR, some of next year's contracts may be cut by 15 to 20 per cent Most of the current contracts range from $12,000 to $40,000. In an average contract of $25,000, some $14,300 goes for the salaries of research workers, $5,000 for equipment, travel, and so on, and the remaining $5,700 to the university for overhead expenses.

There are other indications that ONR is preparing to cut back the scope of its support of basic science It is planning to expand its naval sciences division, which finances studies connected with the development of rockets, jet propulsion and other military projects. Within two years this division will take a larger percentage of ONR's budget, thereby reducing the share for basic research.

For these reasons among others, scientists are now pressing concertedly for immediate enactment of the National Science Foundation Bill. ONR has tided them over what would otherwise have been a lean postwar period. Without an ONR, scientific work in the universities at this moment would be very seriously curtailed.

Many scientists regret that the scientific community at the end of the war did not achieve the realism and purpose exhibited by the naval officers who founded ONR. The organizers of ONR under-

stood political realities and got what they wanted. While scientists debated *whether* the Government should support basic research, ONR's founders, sensing that events had already settled that question, addressed themselves to the question of *how*. If scientists had adopted the same approach, the National Science Foundation might well be in existence. In any case, scientists are grateful to ONR for demonstrating the inevitability of such an organization.

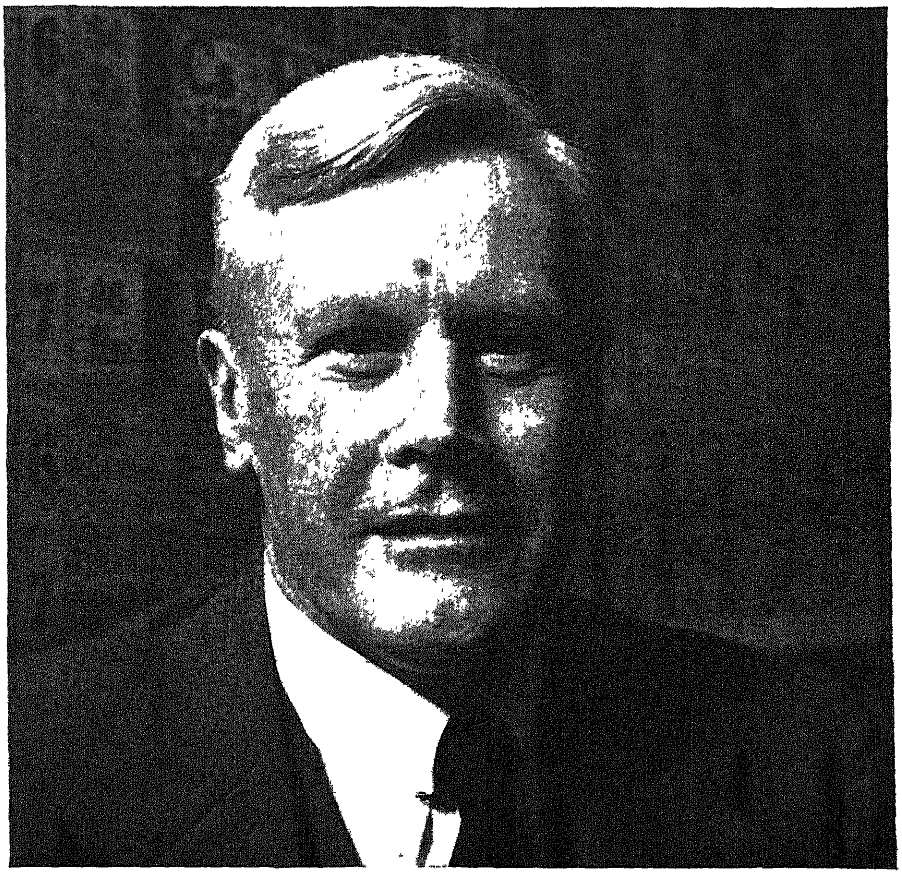
The National Science Foundation is now regarded as "imminent." Its chances are enhanced by the proposed establishment of a Cabinet post and executive department for social welfare, under which a science foundation would logically find its place. Scientists who are interested in the foundation, considering the major issue settled, are already working on the problem of getting an adequate appropriation. The President's budget proposes $15 million for the foundation's first year. Many scientists have written letters to the presidents of their universities urging an appeal to the President to raise the initial appropriation to $50 million as recommended in the famous Steelman Report. A memorandum accompanying these letters points out that advisory panels of ONR have approved basic-research projects totaling some $25 million which cannot be undertaken because of lack of funds.

MEANWHILE ONR, whether or not a science foundation comes into being, has no intention of going out of business. Contrary to the impression of many scientists, it does not consider its support of basic science a stopgap enterprise. To be sure, the Navy officially supports the proposal for a science foundation, and it might perhaps willingly transfer up to 25 per cent of its projects to such a foundation. But Admiral Solberg and others made it clear that, foundation or no foundation, ONR intends to continue to sign contracts with scientists for many fundamental studies—a policy which it considers absolutely essential to the continued technological improvement of the Fleet.

ONR takes a justifiable pride in its pioneering accomplishment. It likes to quote a remark made two years ago by Admiral Bowen, which contains more than a grain of truth: "You could move the Office to another building, put a new sign over the door reading 'National Science Foundation,' and you would have considerably more than the nucleus of such an agency."

John E. Pfeiffer was the author of Enzymes, *which appeared in the December issue of this magazine.*

REAR ADMIRAL THORVALD A. SOLBERG is the present Chief of Naval Research. He was head of the Naval Boiler Laboratory at Philadelphia.



ALAN T. WATERMAN is Chief Scientist of the ONR. Formerly a Yale University physicist, he was an official in the OSRD during the war.

TRIAL BY NEWSPAPER

Being an account of the ordeal of Edward U. Condon, or a case study of the press. The treatment of the affair in nine New York dailies is here dissected

by Joseph T. Klapper and Charles Y. Glock

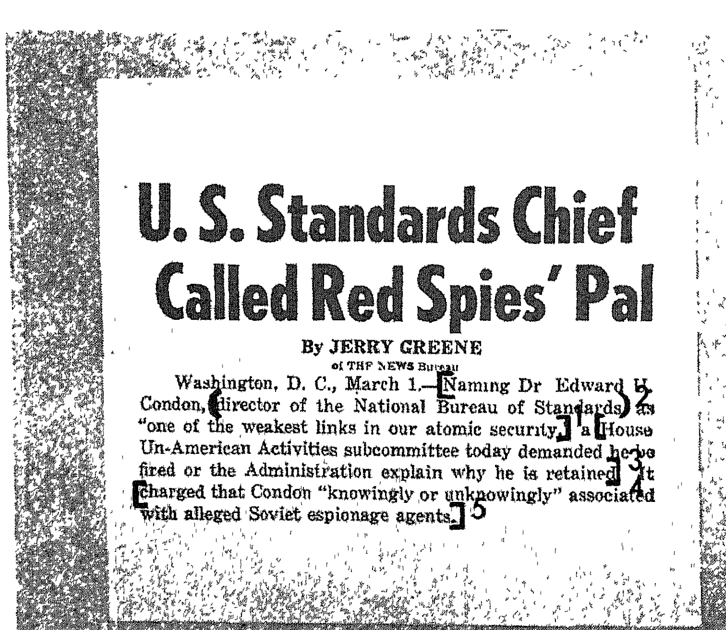
ON March 2, 1948, a subcommittee of the House Committee on Un-American Activities denounced Edward U. Condon, Director of the National Bureau of Standards, through the medium of the U. S. press. The subcommittee asserted that Dr. Condon "appears" to be "one of the weakest links in our atomic security." Its report, quoted in part by various newspapers, presented 27 paragraphs of "information . . . in substantiation of this statement." Part of this information consisted of excerpts from a letter written by FBI chief J. Edgar Hoover to Secretary of Commerce W. Averell Harriman.

Simultaneously the Department of Commerce, under which the Bureau of Standards operates, announced that Dr. Condon had been unanimously cleared by the Department Loyalty Board five days previously. Dr. Condon himself at once denied the subcommittee's allegations, asserted his loyalty and reliability, and shortly thereafter expressed his eagerness for a public hearing by the Committee—an eagerness which he had expressed several times previously in response to similar accusations made by its chairman, Representative J. Parnell Thomas, in magazine articles published a year before.

During the succeeding four and one-half months the "Condon case" became a *cause célèbre*. At least three Congressional committees, the Federal Bureau of Investigation, the Atomic Energy Commission, two executive departments and President Truman himself played speaking roles in the drama. Numerous learned, scientific and juristic societies, as well as various individuals, eminent and otherwise, issued statements. In the course of the controversy, the Administration's refusal to surrender the FBI letter to Congress led to extraordinary Congressional repercussions, including an attempt to write into law certain provisions regarding the retention and release of data to Congressional bodies. The Condon case itself for a time became only an incident in this argument. It was revived on various occasions, however, by additional attacks on Dr. Condon and by statements in his support. From time to time the Committee promised to grant Dr. Condon a public hearing, but the hearing never took place. The case continued to be argued in the press, albeit less frequently, even after the Atomic Energy Commission announced on July 15 that "on the basis of the voluminous record before it, the members of the Commission" were fully satisfied as to "Dr. Condon's loyalty to the United States" and considered his clearance for access to restricted data to be "in the best interests of the atomic energy program."

The Committee on Un-American Activities itself has made no formal determination of its charges against Condon. The case has been conducted largely in the press. Many citizens have become concerned about the affair as a striking example of what has sometimes been called trial by newspaper. They believe that the Condon case poses the question of the responsibilities of modern organs of mass communication toward the liberties and reputations of individuals

As a result of this interest, the Bureau



U. S. Standards Chief Called Red Spies' Pal

By JERRY GREENE
of THE NEWS Bureau

Washington, D. C., March 1.—Naming Dr Edward U. Condon, director of the National Bureau of Standards as "one of the weakest links in our atomic security," a House Un-American Activities subcommittee today demanded he be fired or the Administration explain why he is retained. It charged that Condon "knowingly or unknowingly" associated with alleged Soviet espionage agents.

STATEMENTS

1 Naming Dr. Edward U. Condon, as "one of the weakest links in our atomic security,'

2 Dr. Edward U. Condon, director of the National Bureau of Standards

3 House Un-American Activities subcommittee today demanded he be fired or

4 House Un-American Activities subcommittee today demanded the Administration explain why he is retained

5 It charged that Condon "knowingly or unknowingly" associated with alleged Soviet espionage agents.

CONTENT ANALYSIS in this case begins with identification of statements, each of which expresses a single assertion. Here five statements in the first paragraph of a news article in the *Daily News* are isolated and marked and then listed in table at right. Each statement is now ready for objective classification and analysis.

of Applied Social Research of Columbia University was asked by SCIENTIFIC AMERICAN and six eminent scientists to conduct a study of the press treatment of the Condon case The scientists were· Harrison Brown and Harold C Urey of the University of Chicago, Philip M Morse of the Massachusetts Institute of Technology, George B Pegram, Dean of the Columbia University Graduate Faculties; Charles Lauritsen of the California Institute of Technology. and John C Warner of the Carnegie Institute of Technology

The study that was undertaken is known in communications research as a "content analysis." In general terms this means a detailed examination of verbal or pictorial material for the purpose of providing an objective description of the material For example, a literary critic who analyzes the novels of a given century to determine their political tenor is, in a sense, performing a content analysis. Students of mass communications, however, use the term in a narrower sense. They mean by it a study in which the material is classified according to objective criteria and thus rendered susceptible of statistical description.

The term itself, and the conscious practice of this discipline, are relatively new in social science, as is the whole field of communications research It is only during the last 30 years that such giants of communication as the modern press, the radio and the screen have come to address and to influence whole populations at once. And it is only in the last decade or two that social psychologists have taken systematic note of these forces of opinion. Content analysis is one of several techniques they have developed for the objective study of the media of communication.

Content analysis has already been successfully employed in a number of complex inquiries. The treatment of minority groups in popular fiction, for example, has been examined through a content analysis of magazine stories During the war content analysis was used with some success by Government agencies to predict enemy actions Certain characteristic modes of speech were observed to have increased in frequency during enemy propaganda campaigns preceding surprise invasions. By observing the frequency of such modes of speech in current propaganda, U S analysts were able to note when a new invasion move appeared to be imminent

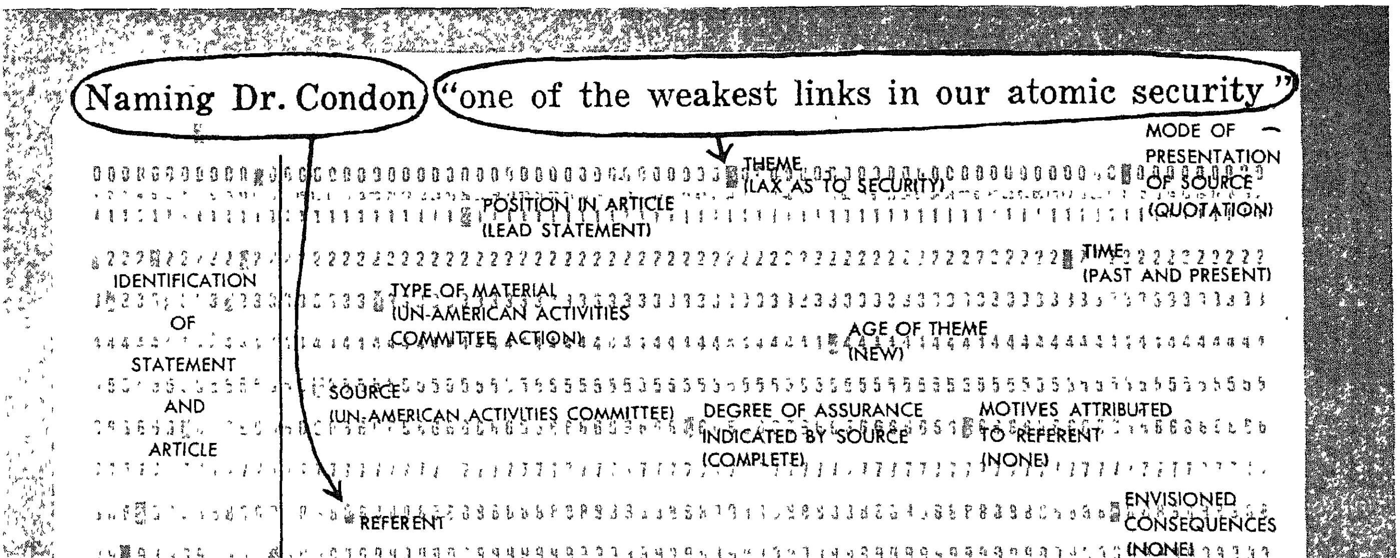
> EDITOR'S NOTE
>
> This study of the press treatment of the Condon case was conducted by the staff of the Columbia University Bureau of Applied Social Research, of which Robert K. Merton is acting director. It is one in a series of researches by the Bureau on the role of mass media of communication in U. S society

The Method

The Bureau of Applied Social Research and the sponsors of the analysis agreed at the outset that the study would be directed entirely to the press treatment of the Condon case, as distinguished from the case itself. Neither the Bureau nor the sponsors considered themselves qualified to evaluate or analyze the activities and statements of the various agencies and individuals involved. No attempt has been made, for example, to assess the truth or falsity of the charges brought against Dr. Condon We have been content with noting in detail what charges against Dr Condon were reported in the press, what support for these charges was there offered, and the like.

It was soon found that to analyze the material on the Condon case in a representative cross section of the whole U S. press would be a huge task: even to determine what papers would constitute such a cross section would involve a research project of no mean dimensions. It was therefore decided to focus the study on the press of a single large city. Because of the number and variety of its dailies, the New York City press was selected Material was drawn from all of the nine general daily papers of that city, *viz*, the *Times*, the *Herald Tribune*, the *Daily News*, the *Daily Mirror*, *PM* and its successor the *Star*, all morning papers; and the *Sun*, the *World-Telegram*, the *Post Home News* and the *Journal-American*, all evening papers, some of them with week-end editions. The period studied was from March 1, 1948, to October 31, 1948, inclusive, *i e.*, from the issuance of the subcommittee report to a date three and a half months after the Atomic Energy Commission had cleared Dr. Condon.

The Bureau set out to approximate as closely as possible a complete coverage of all news articles on the Condon case in all issues of the nine New York newspapers during the given period. This coverage was sought by two independent



STATEMENT is classified in descriptive "dimensions." These include name of person or group to whom the statement refers (the "referent"), its theme, source, date, etc. Punched holes in coded card give a complete description of the statement. A statistical analysis is then made by running all cards through sorting machine.

means. All the papers were asked for a list of the dates on which articles mentioning Dr. Condon were published (replies were received from every paper except the *Mirror*). Library editions of all papers were then searched for the articles published on those dates In addition, a press clipping service was retained to make an independent search of all available editions of the nine papers for the entire period covered Despite the precautions taken, it is quite possible that some articles or references to the case may have been missed. There may be variations in completeness of coverage from paper to paper. Any misses that occurred may be considered random, however; the missing material, if any, would not significantly affect the findings, which are almost always stated in terms of ratios or percentages.

All the relevant material in each news article was divided into "statements," each statement consisting of a single complete idea, *e.g.*, "Dr. Condon was denounced by the Thomas Committee." A statement might be a sentence or a single word; for example, "The martyred Dr. Condon will be called to testify" contains two statements: one that Dr. Condon will be called to testify, the other that he is martyred. The total number of statements in the 306 news articles examined was 4,589. Of these, 680 neutral statements of identification (*e.g.*, "Dr. Condon is director of the National Bureau of Standards") were eliminated, since analysis of them seemed purposeless. This left 3,909 for analysis.

The statements were then classified in various categories known as "dimensions," such as the identity of the person or group to whom the statement referred (called the "referent dimension"), the paper in which it appeared, the theme of the statement, the person or group who made it, the basis offered for the statement, and so on. There were 23 such dimensions. The crucial part of this process was the classification of the theme of the statement. To make this as objective as possible, the themes were subdivided at the outset into numerous specific categories, so that the classifiers or coders were not asked to decide whether a given statement was "favorable" or "unfavorable" to the referent (*e g.*, Dr. Condon), but to describe it in terms of what it actually said. For example, a statement such as, "Dr. Condon is alleged to have associated with a Soviet spy" was classified under the theme: "Association with person in Soviet or Soviet-satellite circles who is allegedly subversive or an espionage agent." These various specific categories were later grouped under more general classifications to furnish the basis for analysis. Thus the statement quoted above became part of a group headed: "Association with allegedly questionable persons." This group of statements in turn eventually was placed in the general category of statements unfavorable to Dr Condon

The statements were all coded on the basis of the original specific criteria. As a check on objectivity, each statement was coded by at least two different individuals, and discrepancies were submitted to several independent checks by supervisors. Thus every coded statement was the end product of a process involving the detailed breakdown of an article, the isolation of the statement, its classification by two different coders in 23 dimensions, comparison of the two codings, and final approval for the next operation

After they were coded, the statements were recorded on International Business Machine (Hollerith) cards. It thus became possible to determine quickly, by means of IBM sorters, precisely what "dimension combinations" existed, and in what degree. If it seemed desirable to know, for example, how many times the *Sun* reported a demand upon President Truman for release of the FBI letter, the machine was merely set to pick out the cards punched 1/8 (column 1—hole 8: *Sun*), 18/5 (referent: Truman), 33/7 (demand for release of FBI letter). The results of the various machine "runs," taken individually or compared with one another, comprise the findings.

Despite the pains taken to ensure the highest possible degree of consistency, accuracy and objectivity, it must be remembered that we are here dealing not with the relatively stable phenomena of the physics laboratory but with the subjective phenomenon of language, which is as variable as human thought. Some degree of flexibility and interpretive inconsistency is therefore inevitable. While this margin of error is believed by the Bureau to be at the very minimum consistent with the nature of the task, one must lean backward in the interpretation of the findings. A very small percentage difference in two contrasted types of press treatment may not be significant in some cases; a notable percentage difference, however, can safely be regarded as significant.

The problem of the present study was to determine the nature of the "trial by newspaper" that Dr. Condon had received in the New York press. This involved a statistical measurement of the extent to which the newspapers treated him favorably or unfavorably. To that end the objective description of the press content on the case was analyzed as to the number of statements critical of Dr. Condon and those sympathetic to him; the number reporting demands for the FBI letter and those reporting refusals, and a miscellaneous category of statements that may be classified as neutral to Dr. Condon.

A statement was classed as unfavorable to Dr. Condon if it criticized him directly or reflected on him indirectly by supporting the Un-American Activities Committee's treatment of the case. An example of the first type of statement is: "Dr. Edward U. Condon . . . accused by a Thomas subcommittee . . . of associations with Soviet spies." An example of the second type. "McDowell insisted that the Committee's previous labeling of Condon stands as an 'almost perfect description.'" Similarly, a statement was classed as favorable to Dr. Condon if it supported him directly (*e g*, "Dr. Condon . . . whose integrity and patriotism have been fully recognized by his scientific peers"), or criticized the Committee (*e g.*, "The . . . Committee's attack on Dr. Edward U. Condon was condemned today as 'irresponsible' by 200 leading scientists").

Thus the statements on each side could be broken down into two categories: 1) anti-Condon and pro-Committee, 2) pro-Condon and anti-Committee. As will be seen, such a breakdown produced some interesting findings.

Analyses were made of the emphasis given to the respective statements and of the way in which they were presented. It must be kept in mind that this is not a study of the editorial statements made by the papers themselves but of their news coverage of the story; that is, of the statements made in the news columns by reporters and their sources. Obviously what a newspaper reports about an event is shaped to a large extent by the event itself. When a paper reported an event unfavorable to Dr. Condon it was under no obligation to create an event sympathetic to him to furnish a balance. Thus the fact that a paper may have reported more unfavorable than favorable events is not in itself necessarily a sign of bias. Bias may be shown, however, in the manner in which a paper reports an event and in its selection of which events to report and which to omit. An outside observer, lacking the newspapers' access to the events on which they based their reporting, can only judge their treatment of the Condon case by comparing the way in which the various newspapers dealt with the same events.

What Was Said

The first general finding is that in the New York press taken as a whole there was a preponderance of statements favorable to Dr. Condon. Of the 3,909 analyzed statements, 745 or 19 per cent were unsympathetic to Condon, and 971 or 25 per cent were sympathetic. These proportions, applying as they do to the total coverage by the entire New York press, are not particularly meaningful: few persons would consistently have read all nine papers and been exposed to this comprehensive coverage. More significant are the differences among the

papers. The range of these differences is indicated in the percentages of pro-Condon and anti-Condon statements in the individual newspapers.

	Pro	Con
Times	65	35
Herald Tribune	64	36
Star	63	37
Post	57	43
World-Telegram	50	50
News	49	51
Mirror	47	53
Sun	43	57
Journal-American	18	82

(Because the *Journal-American* published relatively little on the Condon case, the findings for this paper may be less meaningful than for the others.)

Most of the pro-Condon statements were contributed by the first four papers—*Times, Tribune, Star* and *Post*—which accounted for nearly two thirds of the total New York coverage of the story in terms of number of statements. In the four papers taken as a group, statements sympathetic to Dr Condon outnumbered unsympathetic ones in a ratio of 17 to 10. In the other five papers, which have a much larger total circulation than the first group, statements unsympathetic to Dr. Condon predominated in a ratio of 13 to 10 for the group as a whole.

Analysis of the two categories of statements on each side of the case—*i e.*, those relating directly to Dr. Condon and those relating to the Committee—revealed another interesting difference in the handling of the case by the two groups of papers. There were few statements in praise of the Committee's treatment of the case of the total of the anti-Condon statements in all the papers fewer than one in 13 supported the Committee itself. When it came to the pro-Condon statements, however, there were contrasting results in the amount of criticism of the Committee in the two newspaper groups. In the *Times, Tribune, Star* and *Post*, more than one third of the statements on Dr. Condon's side consisted of criticisms of the Committee's procedure. In the other five papers, this proportion was nearer one fourth. In other words, the second group published a substantially smaller proportion of statements criticizing the Committee than did the first group.

The statements favorable and unfavorable to Dr. Condon taken together accounted for 44 per cent of the 3,909 on the case. Of the rest, a surprisingly large group—some 15 per cent of all statements—concerned the struggle between Republican Congressmen and the Administration over the release of the FBI letter The remaining 41 per cent of the statements in the case were classified as descriptive background of a neutral character.

A further breakdown showing how the

CALENDAR OF EVENTS

REACTION OF PRESS.

MARCH 1 Condon called "weakest link" by Un-American Activities Committee.

Assistant Secretary of Commerce Foster announces Condon cleared by Commerce Department Loyalty Board.

Condon issues statement.

2 Congressman Thomas directs Committee counsel to issue subpoena for FBI material allegedly in possession of Secretary of Commerce Harriman.

3 FBI files are subpoenaed

4 Condon asks Senate-House Committee on Atomic Energy (Hickenlooper Committee) to investigate attacks on scientists in Government employ.

Harriman refuses to honor subpoena

Washington Post discloses Un-American Activities Committee report omitted important paragraph of FBI letter

6 Hickenlooper Committee considers conducting investigation suggested by Condon.

7 Condon interviewed on radio.

8 Hickenlooper Committee agrees to conduct investigation suggested by Condon.

Commerce Department aides are subpoenaed for appearance before the Un-American Activities Committee.

10 Committee charges Commerce Department juggled dates of Condon clearance

24 Committee announces public hearing for Condon will be held April 21

28 Plans for dinner in honor of Condon are announced by Einstein and Urey.

29 Condon's counsel demands certain judicial rights in hearing

APRIL 7 Committee approves a resolution by which the House is to demand FBI file on Condon.

12 Condon speaks at dinner in his honor.

22 House passes resolution to demand FBI file

24 Commerce Dept. formally declines to honor resolution.

MAY 1 Republican National Committee chairman Reece demands showdown regarding Administration retention of loyalty data.

5 Commerce Department announces that material bearing on Condon is now in President's possession

8 Commerce Department reveals Condon, in letter to Foster, agreed to public release of FBI data.

Department of Commerce refuses to release data.

9 President's "own" Loyalty Board announces that it will await final action by Committee before taking action.

10 Condon is revealed by Sawyer to have voluntarily curtailed his activities pending final clearance.

13 Hoffman Bill, growing out of resolution of April 7, passes House

Attorney General Clark accuses Committee of "stealing" Condon data.

Committee replies to Clark charges.

JUNE Activity slight.

JULY 15 Atomic Energy Commission announces that Condon has been cleared.

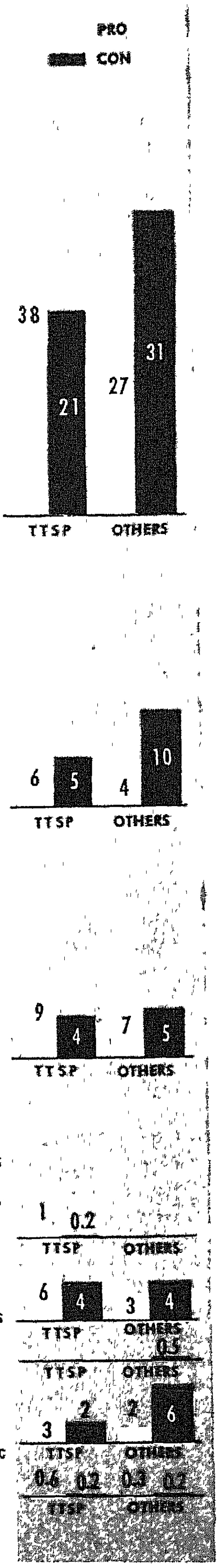
16 Committee attacks AEC clearance.

AUGUST Activity slight.

SEPTEMBER 17 Committee again denounces Condon.

18 Civil Liberties Union urges Committee grant Condon public hearing.

OCTOBER Activity slight.



CALENDAR of developments in Condon case shows how events shaped coverage of the story by newspapers. Bars at right indicate month by month percentages of statements favorable and unfavorable to Condon in two groups of papers. TTSP denotes *Times, Tribune, Star* and *Post.*

treatment of Dr. Condon fluctuated during the progress of the case also yields significant information. In April, when the battle over the FBI letter reached its peak, the reflections of this event were markedly different in the two groups of newspapers. The *Times, Tribune, Star* and *Post* continued to give greater attention to the Condon case itself and to publish more pro-Condon than anti-Condon statements, although the ratio for the group fell to 12 to 10. In the other five papers, however, statements about the letter actually outnumbered statements about the Condon case proper, and the ratio of statements unsympathetic to Condon rose to 23 to 10. When the Atomic Energy Commission cleared him in July, the *Times, Tribune, Star* and *Post* presented a 14-to-10 ratio of statements favorable to him, but the other five papers, in spite of his clearance, remained on the other side of the fence; in that month they printed an average of 11 anti-Condon statements for every 10 pro-Condon. Thereafter there was relatively little press activity on the Condon case, but in September, when the Un-American Activities Committee promised new "shocking revelations," the statements published in the group of five papers were 26 to 10 anti-Condon. In other words, two months after his AEC exoneration, the five papers were still presenting a predominantly unsympathetic picture.

These are simply objective data revealed by the analysis. Whether they show that the New York press was fair or unfair in its coverage of the case is a matter of interpretation, which is beyond the scope of this analysis. The interpretation will depend on the standards applied by the observer. Some may consider that justice would have been served by a perfect balance of pro- and anti-Condon statements in a paper's reporting. On this point, however, the analysis developed certain other pertinent data.

The data had to do with the sources, character and repetition of statements on the case. Because this analysis dealt with statements concerning Dr. Condon himself, the findings from this point will include only statements directly pro- and anti-Condon; *i.e.*, they exclude the statements for and against the Committee. Of the statements against Dr. Condon, 88 per cent were made by members of the Un-American Activities Committee directly or in excerpts that they quoted from the FBI letter. The accusations against Dr. Condon were virtually a monopoly product of the Committee, for some of the remaining 12 per cent of anti-Condon statements were made by Dr. Condon himself or by his defenders in reviewing what the Committee had said about him.

On the other hand, the sources of the pro-Condon statements were legion. They included two departments of the executive branch of the government, the Commerce Department Loyalty Board, the Atomic Energy Commission, entire departments of leading universities, and dozens of scientists and scientific societies Analysis of the weight given by the various papers to the sources of these statements yielded significant differences. The *Times, Tribune, Star* and *Post* gave considerably more attention to the width of Dr. Condon's support than did the other papers; 21 per cent of their pro-Condon statements were attributed to scientists and scientific societies, while in the other five papers only 4 per cent of the statements favoring Condon came from these sources. Indeed, it appears that those five dailies all but ignored the multitude of meetings, letters and statements in defense of Condon by reputable scientists and institutions. As a result, 77 per cent of the case for Dr. Condon as presented to the readers of those papers came from Dr Condon himself, from representatives of the Administration, or from unnamed sources.

A similar analysis was made of the bases of the anti-Condon and pro-Condon statements and the relative weight given to them. The case against Dr Condon was made up almost entirely of three charges: 1) that he associated with suspected persons, 2) that he was lax in regard to U. S. security, 3) that he was unfit in some other unspecified way.

Of the statements making the first charge, 89 per cent identified Dr. Condon's associates only in vague terms or did not identify them at all. His associates were generally described as persons "alleged" or "known" to be espionage agents, or as Soviet or Soviet-satellite diplomats, or as persons suspected of being subversive, without any specification as to why they were under suspicion or any evidence that Condon knew that his associates were under this vague cloud. Only eight per cent of the statements regarding association actually named his associates, and in most of these cases the charges were equally vague. With regard to Dr. Condon's "laxity," nearly all of the statements were simply assertions, most of them being repetitions of the phrase "the weakest link"; there was little or no specific indication as to how he may actually have endangered national security. In the third category, the allegations were even more vague. Indeed, whatever impression may have been produced on casual readers, the content analysis indicates that the case against Dr. Condon as presented in the newspapers may well have raised a question in careful readers' minds as to whether there was any case at all.

The case *for* Dr. Condon contains a substantial amount of specific material. About a quarter of the pro-Condon statements rest on the fact that he was cleared by official investigations. Other favorable statements are based on "two exhaustive FBI investigations" and several documents, still others on testimonials to Dr. Condon's loyalty and competence from a variety of sources. Yet in comparison with the case against Condon these facts were lightly treated by a majority of the New York papers, which throughout the case gave far heavier emphasis to the allegations by the Un-American Activities Committee than to the support of Dr. Condon from various sources.

How It Was Said

A description of what the press said and what it omitted can give only a relatively superficial picture of its coverage. Equally important is the nature of the treatment, and the manner in which newspaper techniques affected the picture presented to the reader. These factors are difficult to analyze in any objective fashion, but the Bureau approached the problem from several new angles and obtained some fruitful results.

One approach was a test of the material by the criterion of the repetition of statements. In any continuing news story, it is to be expected that a newspaper will frequently find it necessary to review past events as background. In making the selection of what background information to print, the newspaper obviously exercises more selective judgment than it can with respect to the new material, for the background provides many more items from which to choose. If, for example, the Un-American Activities Committee announced that it intended to hold a hearing on the Condon case, the "news" was pretty well restricted to that fact, but in injecting background into the report a paper could choose from among a number of statements, such as that Dr Condon had been accused of associating with spies, that he had been cleared by the Loyalty Board, and so on. Thus it is of considerable interest to see what the papers chose to include as background in their reports as the news developed.

In the analysis of this phase of the newspapers' coverage, all statements printed within two days after an occurrence were classified as "new" and all others as "old." The general finding that resulted from this analysis was that in eight of the nine dailies the "old" or repeated statements built up the case against Dr. Condon more than the case for him. About 57 per cent of the case against him in the papers consisted of revivals of the original charges. On the other hand, criticisms of the Un-American Activities Committee were seldom repeated; only 11 per cent of the statements in this category were revivals.

In every category of statements on the

case except the one that covered criticisms of Condon, new statements outnumbered the old. The newspapers repeated general denunciations of him six times as often as they repeated general statements in his support. If they had published no "old" statements at all, the score for statements directly naming Condon would have been 416 pro to 301 anti, instead of 695 to 631 the other way

There is no reason to believe that this result was deliberate But the fact remains that the reporting techniques employed by the papers served to inflate the case against Condon far beyond its native size

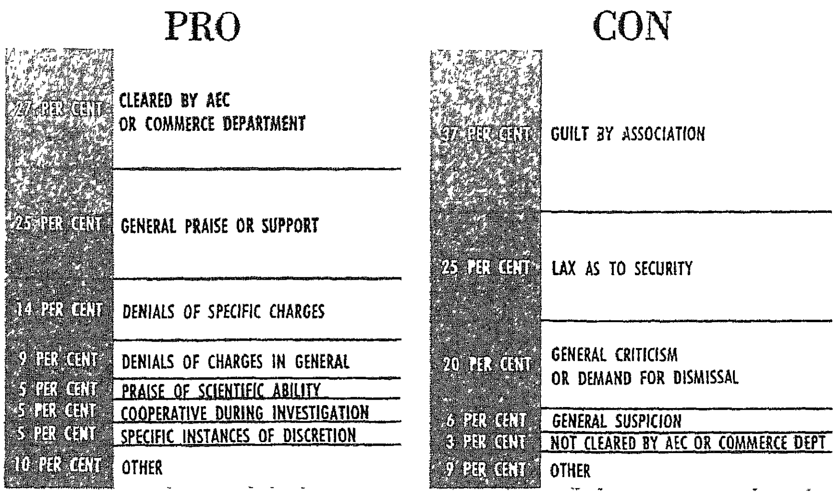
Another significant finding concerns the newspapers' handling of the Committee's promises of a hearing to Dr. Condon, and of the breach of that promise. All the papers reported the promises much more often than the breach Here again, however, there were substantial differences between the two groups of papers. The *Times, Tribune, Star* and *Post* published 14 statements on the Committee's promises for every 10 statements on its failure to keep the promise In the other five papers as a group the ratio was about eight to one.

Summary

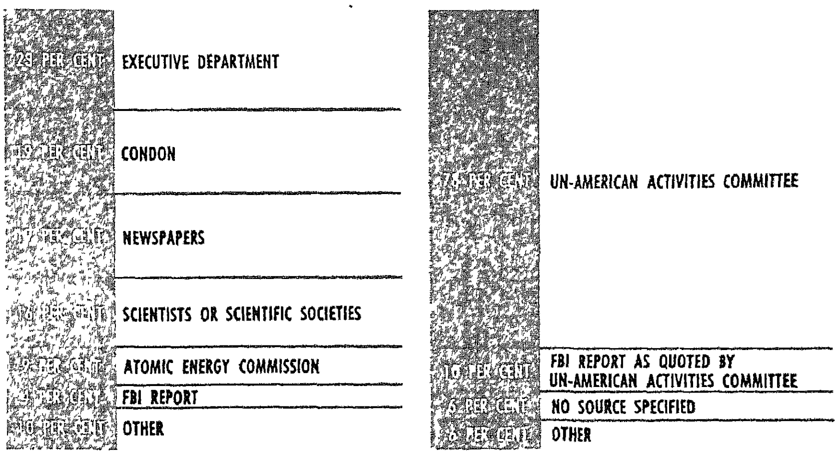
Thus the content analysis produced these principal findings the nine New York papers showed wide variations in their news treatment of the case, although all were reporting the same story. Some presented a picture predominantly favorable to Dr. Condon, some predominantly unfavorable. As reported in all the papers, the charges against Dr. Condon were vague. The width of the support of Dr. Condon received substantial attention in the *Times, Tribune, Star* and *Post* but very little attention in the other five papers. The background material revived for use in the running news stories had the effect of building up the case against Dr. Condon but did not build up his defense to anywhere near the same degree. All the papers reported the Committee's promise to give Dr. Condon a hearing far more often than they reported its failure to do so.

Such are the objective findings. The writers have attempted to avoid judgments, or have labeled them clearly when they seemed unavoidable. How or why the press treatments here described took the form that they did, and whether the papers should be commended or condemned are questions to be considered by interested students of the press

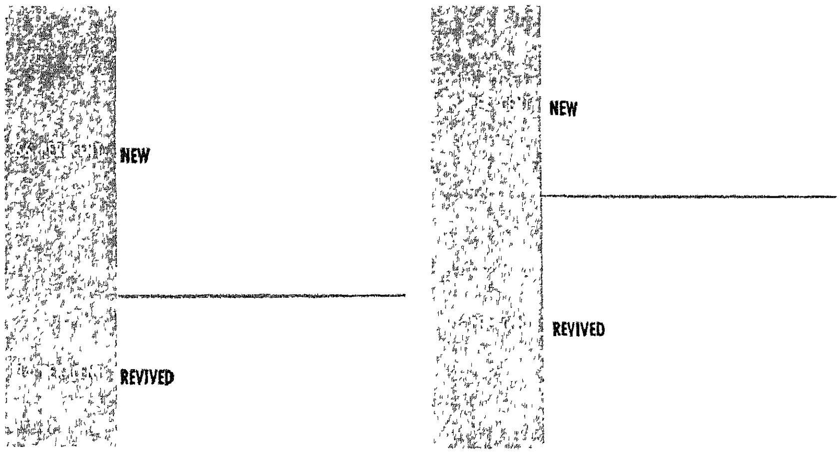
Joseph Klapper and Charles Glock are research associates in the Bureau of Applied Social Research at Columbia University.



CASE FOR AND AGAINST Condon as presented in the New York press as a whole is summed up in this chart showing the percentages of statements in various pro and con categories. Charges against him were invariably vague.



ANALYSIS OF SOURCES of statements shows that anti-Condon case consisted largely of assertions by Thomas Committee. Scientists' defense of Condon got much less attention. "Newspapers" means no source specified.



REVIVED STATEMENTS represent repetition of old material in news stories. The newspapers repeated charges against Condon much more often than they did his exoneration, thus building up attack more than defense.

THE MECHANISM OF LIGHTNING

The dramatic phenomenon of nature is closely studied in the laboratory and in the field. It is found to be an intricate series of physical events

by Leonard B. Loeb

LIKE many other commonplace natural phenomena, lightning has been uncommonly difficult to explain. Although it is two centuries since Benjamin Franklin made a start by showing that lightning was an electrical discharge, not until the present decade have we begun to understand the extraordinarily intricate mechanisms involved in the origin and development of a lightning flash. Recent researches, however, appear to have removed much of the mystery from this awesome spectacle.

Let us begin by considering the atmospheric situation that leads to a lightning storm. Whenever weather conditions produce rapid updrafts of warm, moisture-laden air that rise well above the freezing level in the atmosphere, the region involved becomes a huge generator of static electricity. The water droplets of this thundercloud, in which the updrafts may reach a velocity of 160 miles an hour or more, become electrified. Just how the charges are generated is still a matter of conjecture. It may be that the wind currents tear at the surface of the droplets, producing a fine, negatively-charged spray and leaving the larger droplets positively charged. Another possibility is that electrical fields already existing in the clouds induce charges on falling droplets. Still another is that ice crystals at the upper levels are electrified by friction or by some process that accompanies freezing.

In any case, large masses of charged water droplets and ice crystals become segregated in positively- and negatively-charged groups and collect at different localities within the thunderhead (*see diagram on opposite page*). Between these huge groups of opposite charge very high potential differences and electrical fields develop. It is these highly charged regions of the cloud that account for the split-second electrical discharges called lightning.

As the charged, wind-driven thunderhead approaches a given ground area, electrical fields gradually build up between the earth and the cloud. Near the earth the fields rarely exceed 2,700 volts per centimeter of their length, but even at such a field a vertical conducting rod from the earth only 10 feet long (about 305 centimeters) would have a potential difference of more than 800,000 volts (305 × 2,700) with the uncharged surrounding atmosphere. Such a field would make the hair of a person seated on the ground literally stand on end. It accounts for the corona discharge, popularly called St. Elmo's Fire, which is sometimes seen issuing from a church steeple or from the wingtips of an airplane during a storm.

In a cloud that produces lightning, the area of the charged region generally has linear dimensions of some 1,000 feet. At nearby points the charged region develops fields of 30,000 volts per centimeter, so the field of the cloud is vastly greater than the one at the ground. Thus lightning discharges usually originate at the cloud and work downward. On the other hand, a very tall grounded conductor such as the Empire State Building may develop a potential high enough to initiate a lightning discharge from the earth. Be this as it may, however, the distribution of charges in a thundercloud is such that there are many more discharges within the cloud than between the cloud and the ground. These discharges, largely concealed by the cloud, account for the so-called sheet lightning sometimes seen in distant thunderclouds on dark nights.

Lightning strokes vary in length from 500 feet to two miles or more. Calculations based on the length of these paths and on the fields at the earth indicate that the electrical potential between a thundercloud and the earth is of the order of hundreds of millions to billions of volts. If the space between the cloud and the earth were a vacuum, these huge potentials would accelerate electrons and ions to a speed sufficient to smash the nuclei of atoms. In the air, the accelerated particles cannot attain any such energies, for they are slowed by countless impacts with the air molecules. Nevertheless the power of a lightning stroke remains impressive. The brief currents it generates will vaporize No. 12 copper wire; the magnetic fields produced by a relatively short stroke down a copper tube one centimeter in diameter with walls one and a half millimeters thick will collapse the tube. A lightning stroke which travels down the moist interior of a tree in 30 feet liberates enough heat and steam literally to blow the trunk open.

THE visible flash of lightning is produced by the heating of air molecules in the path of the stroke, which may reach a temperature of 30,000 degrees Centigrade. Camera studies show that the channel of the stroke remains luminous for some 100 millionths of a second after the stroke itself. Owing to the enormous power of the stroke, the channel expands explosively, and this accounts for thunder, which comes from the shock waves produced by the channel's expansion. The explosion of segments of the channel near an observer is heard as a sharp crack; rumbling thunder comes from more distant segments, from repeated strokes and from echoes. These rumbles, it may be noted, cannot be heard as far as those from major gunfire, which indicates that lightning discharges, impressive as they are, do not yield as much power as ordinary man-made explosives, to say nothing of an atomic bomb. The noise of big guns can be heard for a distance of some 15 miles; the audible limit for thunder is only about seven miles.

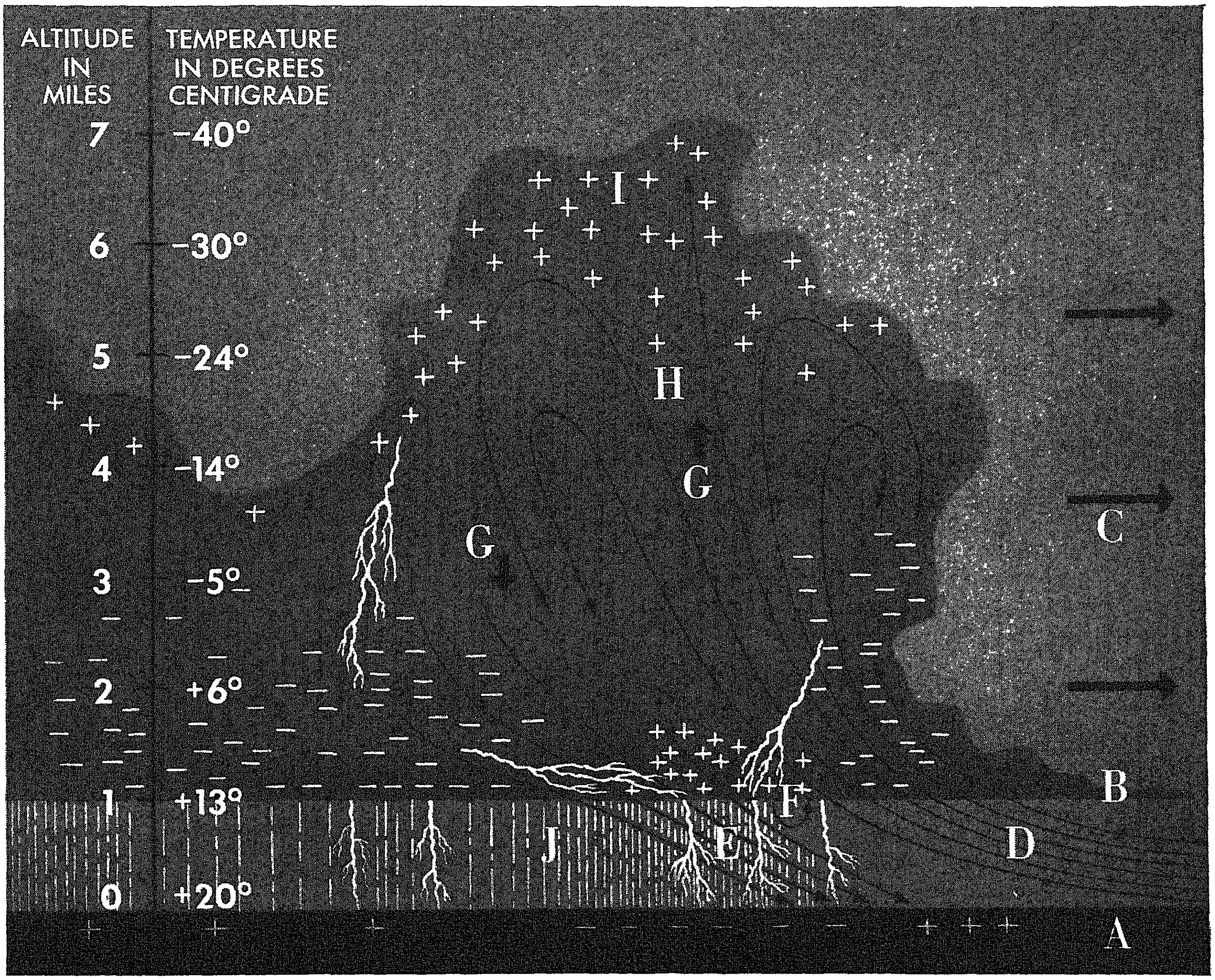
Analysis of the lightning stroke shows that it is very similar to the long sparks that jump the gap between two widely

separated condensers of high potential. Like these sparks, a lightning stroke follows a crooked path and develops branches or forks that advance in the direction of the stroke, so one can always deduce from its branches the direction in which a stroke is traveling. Unlike condenser sparks, lightning does not oscillate back and forth. Damping due to the high resistance of the electrical feeders from which the stroke originates permits it to discharge in only one direction. A lightning stroke may come from a positive or negative cloud, but most strokes, except in mountain storms, are from negative clouds.

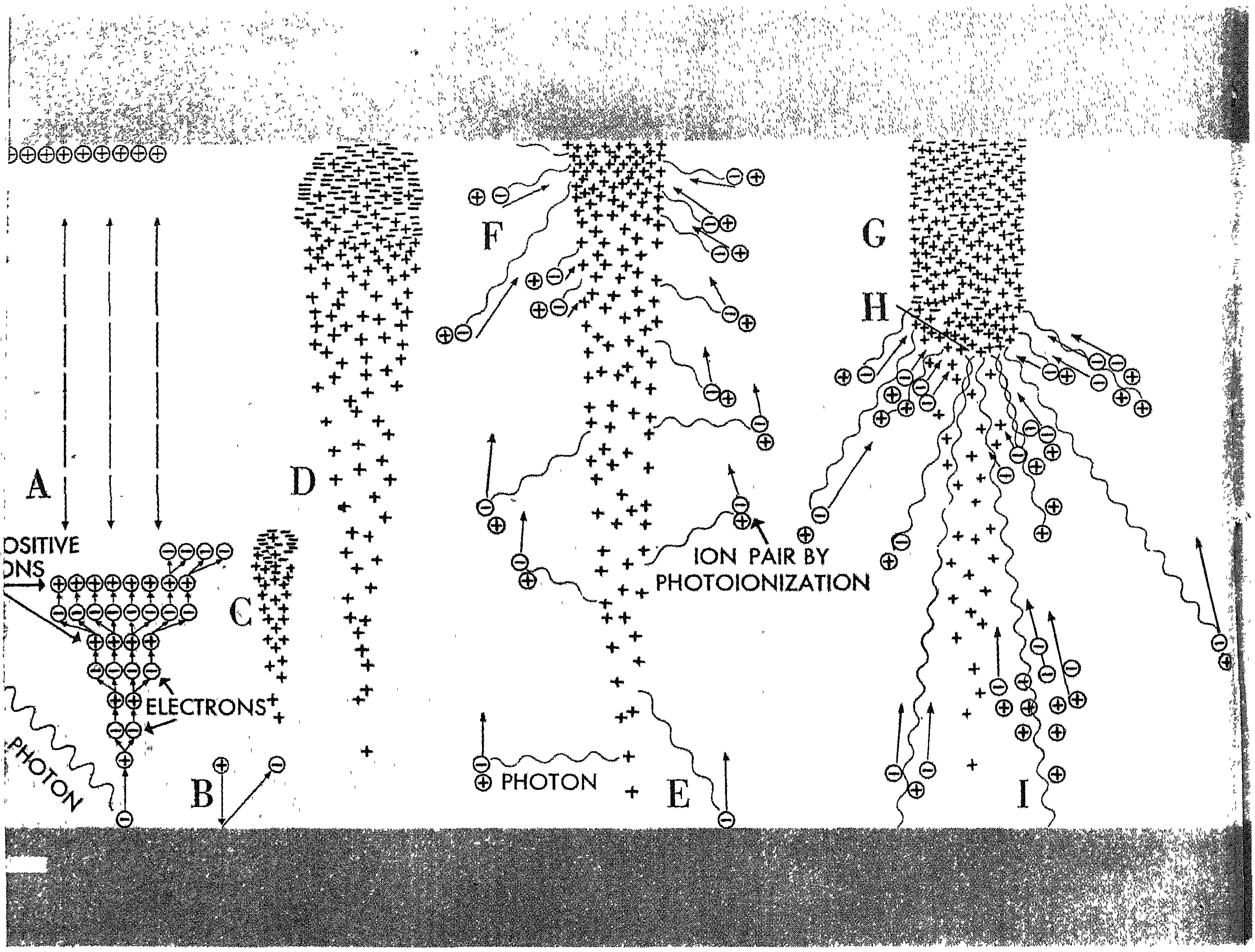
The speed of lightning is no idle metaphor. a lightning stroke travels at a velocity of approximately one billion centimeters per second. It lasts no longer than five to 500 microseconds (millionths of a second), the median being some 30 microseconds. The quantities of electricity involved, however. are huge. a single discharge may transfer 200 coulombs of electricity (a coulomb being the quantity of electricity transferred by one ampere of current in one second); in terms of current a stroke may carry as much as 500,000 amperes. A stroke of 200 coulombs and one billion volts which lasts 200 microseconds produces a thousand billion kilowatts of power

The spark channel down which this huge packet of energy travels at first is tiny—an inch or less in diameter—but the power of the completed stroke expands the channel at the explosive rate of 50,000 inches per second. Thus it is difficult to define the diameter of a lightning stroke, either as it appears to the eye or in a photograph. The lightning channel loses much of its luminosity after it expands to a diameter of a foot or more, so that it appears reasonable to estimate that the visible lightning stroke ranges from an inch to a foot in width.

THESE observations serve to describe the phenomenon, but they do not explain the mechanics of the lightning stroke itself. The basis for an explanation of that fundamental question was laid by several independent studies made just before the recent war. One group of studies, conducted by the writer and J. M. Meek in the U. S. and independently by H. Raether in Germany, analyzed the mechanism of ordinary electrical sparks in air. Other basic information was provided by photographic analyses of the progress of electrical strokes on a microsecond time scale. These were made in South Africa by B. J. F. Schonland and his associates, who used a camera with a rapidly revolving lens to photograph actual lightning strokes, and in England by T. E. Allibone and J. M.



THUNDERCLOUD is a mighty generator of static electricity. The lightning flashes in this drawing are massive discharges between regions of differing potential. Some flashes are within the cloud. Others play between the cloud and the ground. The latter is indicated by A. B is the base of the cloud. C is the wind that drives the cloud. D is the ascending, moisture-laden air current. E is the descending air current. F is the roll or scud cloud. G indicates up and down drafts. H is the region where hail is generated. I is the highest region of ice formation. J is rain falling from the cloud. A scale of height in miles and temperature in degrees Centigrade is at the left.



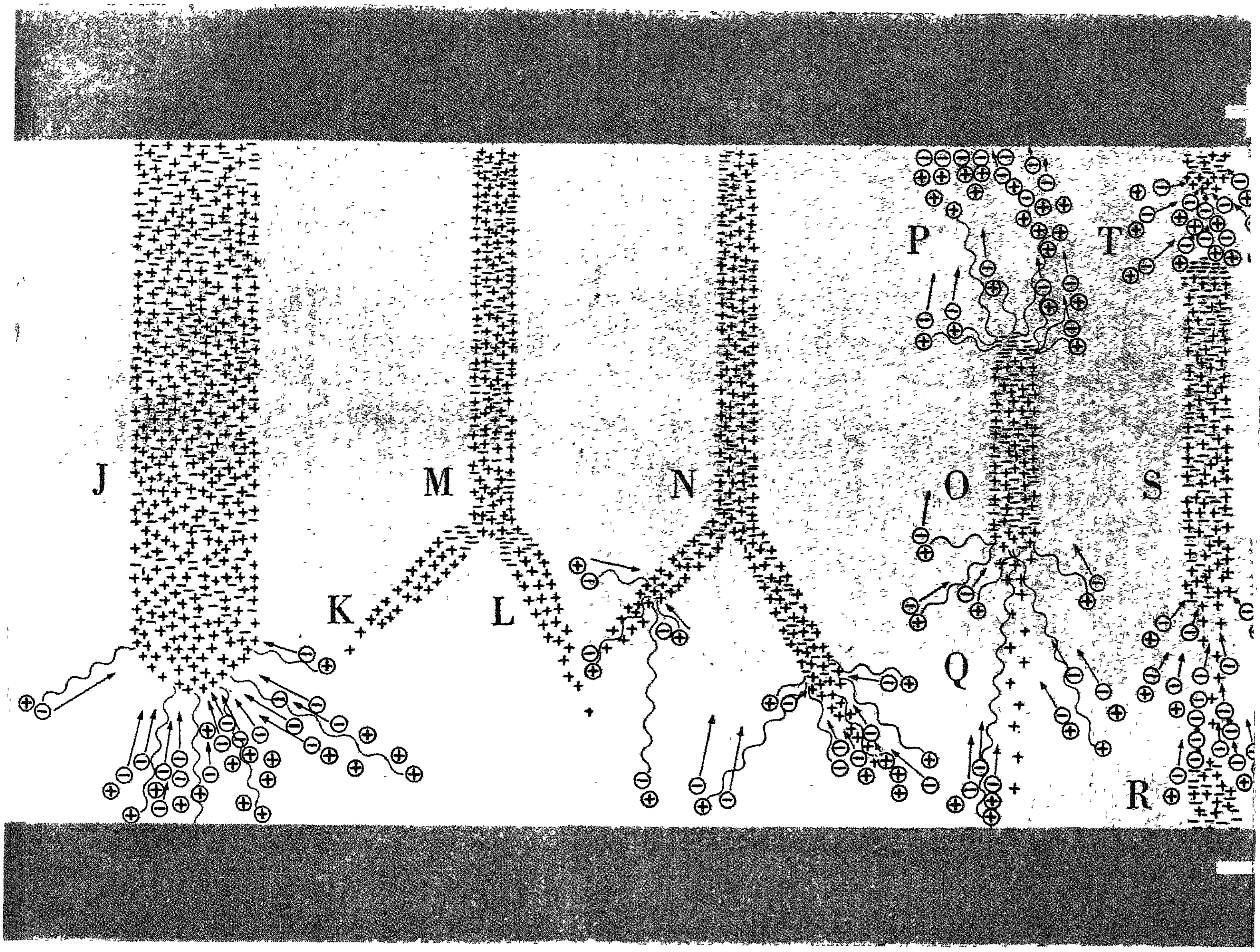
SEQUENCE OF EVENTS in a flash of lightning is outlined by analyzing a discharge between two parallel plates. The upper plate is positively charged; the lower plate, negatively. The field between them (A) has a strength of 30,000 volts per centimeter. At the lower left a random photon knocks a single electron from an atom. Moving towards the positive plate, the electron collides with other atoms to liberate an avalanche of electrons. In the wake of the electrons remain positively-charged atoms, or ions (C and D). These ions reinforce the charge of the positive plate, thus attracting new electrons (F) that have been liberated by radiation (E)

Meek, who made similar photographs of long sparks with a revolving film camera.

The investigation of ordinary sparks showed that the path they follow in the air is created by a so-called "streamer" mechanism. This process begins when air at atmospheric pressure is placed in a field of about 30,000 volts per centimeter, or as little as 10,000 volts if water droplets are present. A single electron starts the process, and there are always stray electrons, liberated by cosmic rays or radioactivity in the air, on hand to start it. The electron, advancing from the negative end of the field towards the positive end, gains energy from the field despite its billions of collisions per second with gas molecules. When it gains enough energy, it begins to knock electrons out of some of the molecules it strikes. These in turn repeat the process, so that the liberated electrons soon become an avalanche. After a run of one centimeter in a field of 30,000 volts per centimeter, the single initial electron produces an avalanche of 10 million free electrons. Raether has photographed such avalanches in a Wilson cloud chamber by condensing water drops on the ions left in the avalanche tracks.

In their wake the freed electrons of course leave large numbers of positively-charged ions, for each molecule from which an electron escapes is ionized. The ions create a positive electrical charge throughout the space in the path of the electrons. When the ions left by the electron avalanche are deserted by the electrons at the positive end of the field, they add to its positive potential. The augmented field soon becomes strong enough to draw photoelectrons, created as an accompaniment to the avalanche process, from the negative side of the field. The photoelectrons, feeding into the ion space-charge left by the initial avalanche, produce more ionization and enlarge the space-charge so that it expands backward towards the negative end of the field. The situation can be pictured by imagining a magnet that by its field draws iron filings from a distant pile in such a way that the filings, building on to one another from the magnet backward, form a path back to the pile.

THE entire chain of events, illustrated in the series of diagrams above, takes place in a matter of microseconds; the avalanche of electrons, for example, ad-



during the previous events. The electrons, in turn, ionize more atoms so that a heavily ionized region (G) begins to extend towards the negative plate. This process continues until there is a bridge of ions (J), called a streamer, between the two plates. It is this streamer that provides the channel for a spark or for lightning. The next drawing illustrates the process by which streamers form branches. A streamer (M) attracts two avalanches (K and L). The avalanches are then reversed to form a branched streamer. The remaining example shows how a streamer may begin before an avalanche has reached positive plate. Streamer then works towards both plates.

vances at the rate of 20 million centimeters per second. The ionized path that is formed as the end result of the process is called a streamer, and it is this streamer that provides a channel for the spark or actual lightning stroke.

In a thunderstorm, such a streamer bridges the gap between the charged cloud and the ground. The bridge is a conducting filament of ions with electrons streaming over it, and it acts as a kind of tear in the electrical field, accentuating the electrical stress at its ends. The instant the bridge is completed, it releases a cataclysmic burst of electrons from the negative terminal—in this case the ground. The burst of electrons sends a potential wave up the streamer channel to the cloud. This literally tears electrons out of most of the molecules in the centimeter-wide channel. The cloud's charge and energy are then drained away down the conducting channel for some 10 microseconds, making the channel brilliantly luminous. The speed of the potential wave, called the return stroke, is from one to ten billion centimeters per second—one thirtieth to one third of the speed of light. This brilliant flash constitutes the phenomenon we call lightning.

Once the spark channel has been established, there may be repeated strokes from the cloud down the same channel. The discharge of the section of the cloud from which the stroke comes changes its potential with respect to other sections of the cloud, and strokes within the cloud then recharge this section, causing new strokes to the ground. As many as 40 successive strokes down a single channel have been observed—the legend that lightning never strikes twice in the same place is wrong in more ways than one. The repeated strokes follow one another very rapidly, at intervals ranging from tenths to hundred-thousandths of a second.

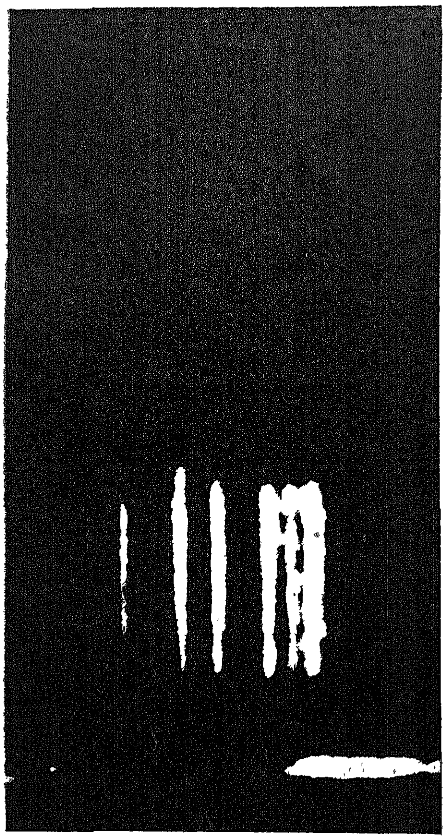
The process that has been described is that for a stroke from a positive cloud to negative ground. For a stroke from a negative cloud the mechanism is similar, except that the streamer is built up by steps.

The foregoing description represents the fundamentals of the process, but in an actual lightning storm the sequence is a bit more complex because of the length of the strokes. When Schonland photographed the lightning discharge with his

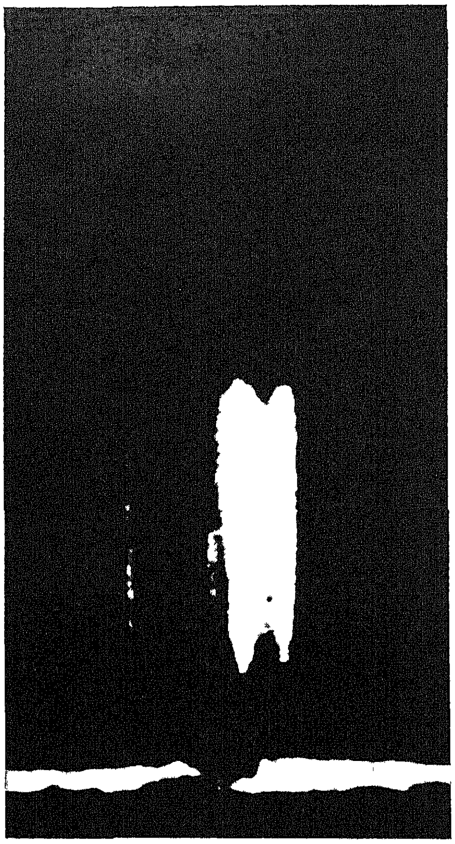
revolving-lens camera, the pictures showed that the stroke advanced in a series of jumps. The mechanism for this process is deduced to be as follows: When a streamer is initiated from the cloud it starts towards the ground as a "pilot" streamer. After some 30 to 90 microseconds, during which the tip of the streamer has advanced 10 to 30 feet, the ionization in the streamer's upper or cloud end decays as the result of the recombination of ions. This builds up a high resistance, and in consequence a high potential, at the upper part of the channel. When the potential reaches a critical limit, the stress is great enough to re-ionize the part of the channel on the earth side of the region of stress. A rapid pulse of ionization then sweeps down the channel, increasing in speed and intensity as it approaches the tip of the streamer. When it reaches the tip, the latter is given a boost in energy. It lights up brilliantly, and often produces branches at this point. The pilot streamer then advances for another 40 to 90 microseconds, whereupon decay again sets in at the cloud end and the process is repeated. Thus the pilot streamer forges ahead, the mechanism being known as the "stepped leader" process.

As the streamer approaches the ground, the field distortion, particularly near conducting elements in the ground, increases. The streamer speeds up and heads in at a nearly vertical angle to the ground. If the stroke is from a negative cloud, in the last microsecond before the streamer is completed a positive streamer may advance from the ground to meet the pilot streamer, usually 15 to 40 feet above the ground. In any case, as soon as the pilot streamer makes contact with the ground or with a positive ground streamer, an enormously steep potential wave sweeps up the channel to the cloud. This return stroke, which ionizes from one to 30 per cent of the gas molecules in the channel, is the lightning flash that we see. After this stroke discharges the section of the cloud to which the channel leads, the cloud is recharged as we have already indicated, and it then yields a new discharge towards the ground. Because the channel is now fully ionized, the discharge proceeds not by steps but directly to the ground. This wave, called a "dart leader," accounts for the repeated strokes of lightning. When the dart leader reaches the ground it calls forth a new bright return stroke. Dart leaders and return strokes repeat themselves in rapid sequence until the cloud element is drained of its high potential.

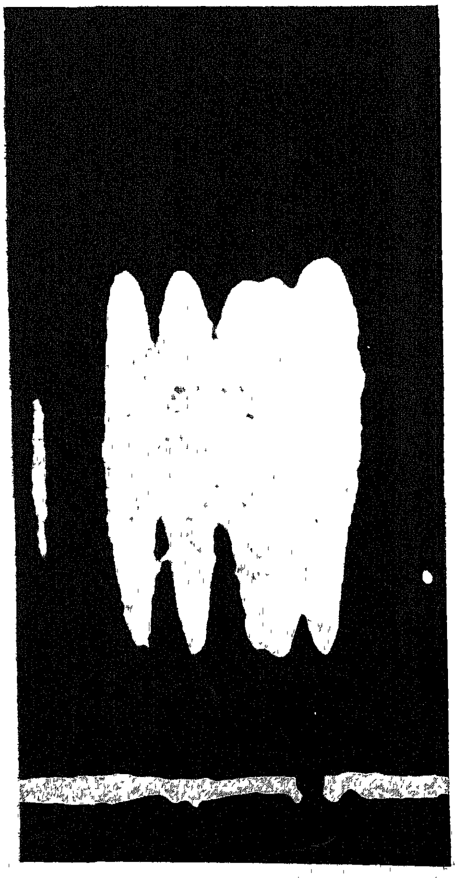
Leonard B Loeb is professor of physics at the University of California.



AVALANCHE of electrons, depicted in drawings on pages 24 and 25, is photographed in a cloud chamber.

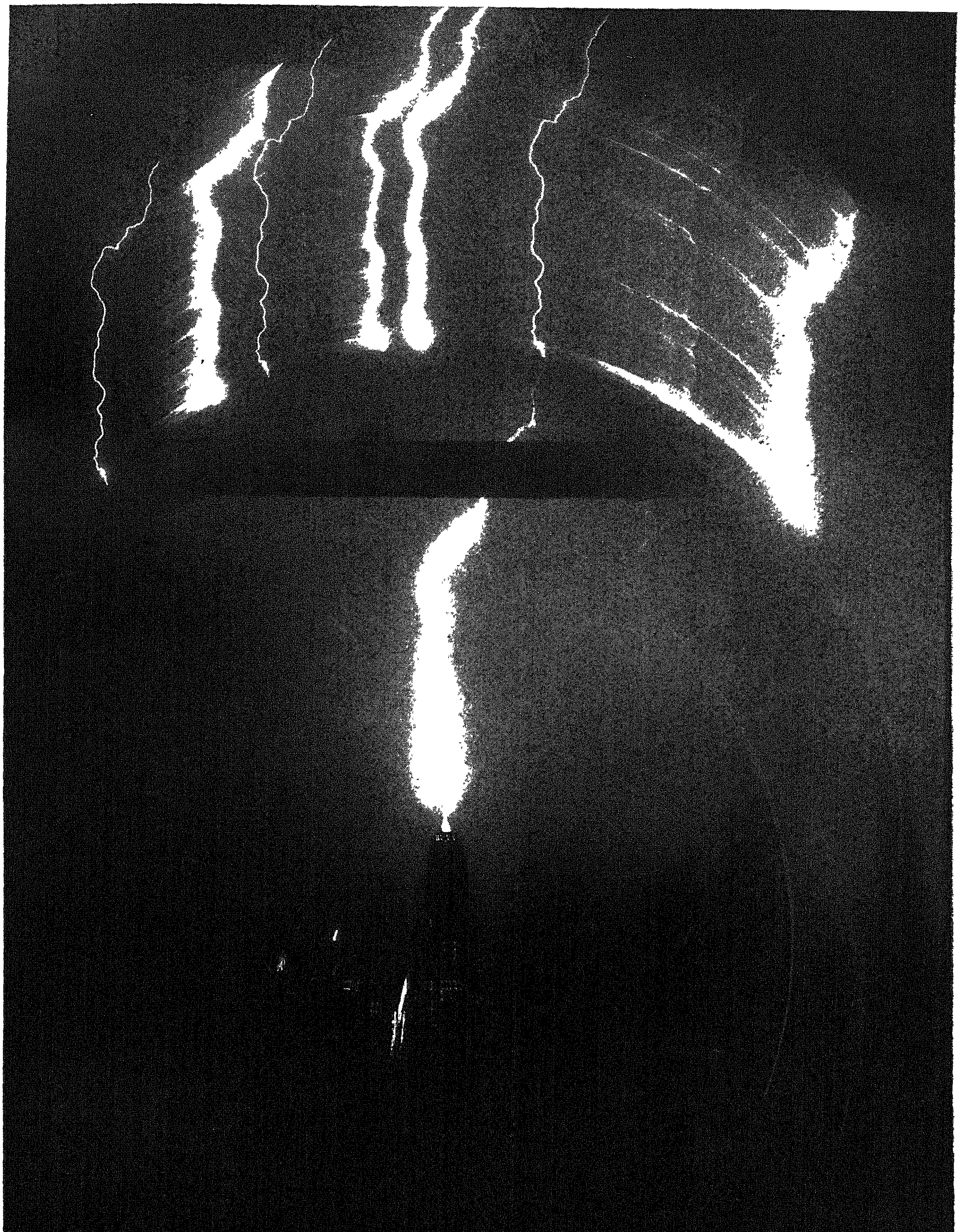


ADVANCE of avalanche within the chamber is apparent in a photograph made tiny fraction of a second later.



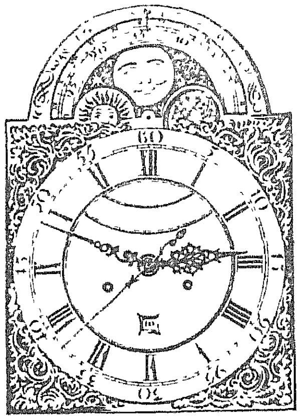
GROWTH of avalanche is shown in third photograph. Electrons ionize atoms so droplets condense on them.

STREAMER develops from another avalanche. These experiments were done in the laboratory of H. Raether.



COMPLEX STRUCTURE of lightning is illustrated by a photograph of a single bolt striking the Empire State Building. This photograph was made by researchers of the General Electric Company with the revolving-lens Boys camera. At the top the stroke is dissected into one long discharge (*at right*) and six subsequent ones.

SCIENCE AND



Legislation

THE 81st Congress already has before it several dozen bills of interest to the sciences. The most important provide for 1) national compulsory health insurance, 2) Federal assistance in setting up local public health services in rural areas, 3) Federal support for primary and secondary schools, 4) a National Science Foundation. All are similar to unsuccessful bills in the last Congress. All but the first appear assured of passage this spring.

The national health insurance bill, one of the principal social measures requested by the President in his State of the Union message, is sponsored in the Senate by Senators Wagner, Murray, Chavez, Pepper, Taylor and McGrath, and in the House by Representative Dingell of Michigan. The insurance system would be financed by payroll taxes and would provide medical and hospital care for 85 per cent of the U. S. population Doctors and hospitals participating in the system would be paid—on either a fee-for-service or a per capita basis, whichever they preferred

The bill to promote rural public health units was introduced by newly elected Senator Chapman of Kentucky. About 40 per cent of the 3,071 counties in the U. S are without full-time public health services. Senator Chapman's bill seeks to remedy this by adding Federal funds to state funds for new units. The money would be apportioned according to each state's need as indicated by its per capita income.

The school aid bill, whose author is Senator Thomas of Utah, would allot funds to the states on the basis of per capita income and the number of pupils. The two troublesome issues that have hitherto blocked Federal school aid—segregated schools in the South and the question of aid to parochial schools—are by-passed in the present bill. The states will be allowed to follow local practices. The President's budget contains a proposal of $300 million for the first year of the program.

The Science Foundation bill failed to go through Congress last year only because of a last-minute legislative jam In this session it is sponsored by three Senators of each party. Thomas, Kilgore and Fulbright, Democrats; and Smith, Cordon and Saltonstall, Republicans. The bill is considered virtually certain to pass unless it is stalled behind the health insurance bill in the Senate Labor and Public Welfare Committee. The President's budget message asked for a $2.5 million appropriation and $12.5 million in contract authorizations to get the Foundation started during the fiscal year beginning in July.

Atomic Energy

PRESIDENT TRUMAN has indicated that he will ask Congress to restore the system of staggered terms for members of the Atomic Energy Commission as originally provided in the Atomic Energy Act The present terms, fixed by the 80th Congress, all expire on August 1, 1950.

A report by the AEC's Industrial Advisory Group finds that industry is not playing a large enough role in the development of atomic energy. Aside from the fairly widespread use of radioactive isotopes in research, there are few companies exploring the applications of atomic energy. The Industrial Advisory Group, headed by James W. Parker of the Detroit Edison Company, thinks that more can be done to encourage industrial participation. It recommends publication of declassified research papers still unpublished; preparation of special technical and semitechnical reports for industry, and reports on the organization of the AEC and its policies on such questions as patents, systematic promotion of personal contact between AEC and scientific and technical personnel in industry, establishment of a larger permanent industrial advisory committee.

The AEC has announced publication of the first volume of its monumental National Nuclear Energy Series. The series, which will include about a third of the 2,400 AEC and Manhattan District papers declassified so far, will run to 60 volumes.

Practical utilization of atomic power moved a step nearer with the award of a contract to the Westinghouse Electric Corporation for a ship-propulsion unit to be built to specifications furnished by the Navy Bureau of Ships. Westinghouse will develop the unit in collaboration with the AEC's Argonne National Laboratory.

The AEC and the Agricultural Research Administration, experimental arm of the Department of Agriculture, also announced results of a large-scale test of the effects of small doses of radioactivity on crop growth. Increased yields and earlier ripening had been claimed by several experimenters Tests in 14 states on 20 crops, from cotton and tobacco to beans and tomatoes, failed to back up the claims.

Atomic Clock

THE first clock in history to be regulated by the spin of a molecule instead of by the sun or stars is now a ticking reality. It was unveiled at the National Bureau of Standards last month by its designer, Harold Lyons. The clock is controlled by the period of vibration of the nitrogen atom in the ammonia molecule.

As explained in "Radio Waves and Matter" by Harry M. Davis (SCIENTIFIC AMERICAN, September, 1948), the clock was developed by the use of microwave spectroscopy. Nitrogen atoms in molecules of ammonia gas under low pressure strongly absorb radio energy at a certain microwave frequency and oscillate in resonance with this frequency. In Dr. Lyons' clock, this resonance frequency is utilized to regulate the frequency of a beam of microwaves. The beam in turn controls an oscillating current driving a conventional alternating current clock.

The ammonia clock has an accuracy of better than one part in 20 million Such accuracy is beyond any attainable in astronomical observations, since these always involve the variable rotation of the earth. The clock gives astronomy an independent yardstick for guiding telescopes and measuring the length of the solar year. The device can also be employed as a broadcasting frequency monitor. Its constancy will make it possible to cut allowances for "drift." As a result, there will be room in the crowded radio spectrum for more television, FM and standard broadcast stations.

Aerobee Rocket

A NEW rocket specifically designed for research in the upper atmosphere has been successful in flight tests at the White Sands, N. M., proving ground. Named the Aerobee, it has carried 100 to 250 pounds of scientific equipment to heights of 70 miles.

The first large high-altitude rocket of American design, it was developed by the Applied Physics Laboratory of Johns Hopkins University under Navy sponsorship to take the place of the dwindling

supply of captured German V-2s. Although it does not have the range of the V-2 (114 miles), it is a more practical and less expensive instrument.

The Aerobee is nearly 19 feet long and very slender (15 inches in diameter). It has two motors: one, burning solid fuel, is jettisoned when the velocity reaches 1,000 feet a second, the other uses liquid fuel. It has no guiding mechanism; its course is set on the launching platform. Data gathered by the instruments in the rocket are radioed to the ground by an automatic transmitter, or are recovered after the rocket falls. An explosive charge blows off the tail during descent and tumbles the rocket end-over-end, slowing the fall to 150 feet a second. Twenty Aerobees have been built. So far three have been fired successfully.

AAAS President-Elect

ROGER ADAMS, dean of U. S. organic chemists, has been elected president of the American Association for the Advancement of Science to serve in 1950. The president for 1949, named by the AAAS Council a year ago, is E. C. Stakman, the University of Minnesota plant pathologist.

Dr. Adams, head of the department of chemistry at the University of Illinois since 1926, is a former president of the American Chemical Society. He is widely known not only for his research accomplishments, but as a teacher. Scores of leading U. S. chemists were his students.

Scientists in Uniform

THE special training and abilities of most of the 50,000 scientists and engineers who served in the armed forces during the war were largely wasted, according to a report just released by the Army. Assignments that could make use of their professional skills were given to only four in 10 of those who received direct commissions as officers, to only three in 10 who entered as reserve officers, and to only two in 10 enlisted men. The rest were used for purely administrative duties, for combat or merely as "another pair of hands."

The report was prepared under the direction of David M. Delo, chief of the Scientific Manpower Section of the Army Research and Development Group. It was based on replies to questionnaires sent to the scientists and engineers themselves. They were practically unanimous in condemning Selective Service and the armed forces' personnel policies. The draft boards, it was said, made those for whom deferment was sought feel like draft dodgers, so that many enlisted or refused deferment and thus were lost to high-priority research projects.

The report recommends that in the event of another war a scientific manpower pool replace Selective Service for scientists and engineers. Those in charge of the pool would control assignment of scientific personnel both to military and to civilian organizations.

Rivalry for Hospitals

CONSPICUOUS waste and duplication in the medical facilities of the armed forces has been reported by the medical task force of the Hoover Commission on Organization of the Executive Branch of the Government.

The group found that in New York, for example, the Army, the Navy and the Veterans Administration are all embarked on large hospital construction programs, although the five existing military hospitals in the area have an overall occupancy rate of only 60 per cent. Some of the patients in the military hospitals, moreover, are properly charges of the VA, which has enough beds to take care of them. The St. Albans Naval Hospital on Long Island is planning to install the largest X-ray machine ever built for cancer therapy, the investigating group observes that patients requiring such treatment are rarely of further military value and should be discharged and sent to VA hospitals.

The group's report outlined schemes for consolidating military hospitals which, it declared, would improve the quality of care and sharply reduce the number of doctors needed by the armed forces. The report also called for a comparable regrouping of Federal civilian medical agencies into a new national bureau of health with three divisions. One would operate all Federal hospitals except military station and field hospitals. The second would merge the public health activities of the Public Health Service and the Food and Drug Administration. The third would consolidate all Federal medical research and training activities.

Vitamin B_{14}

THE discovery of a vitamin, B_{14}, which halts the growth of a type of cancer tissue in the test tube is reported by two investigators at the University of Washington, Earl R. Norris and John J. Majnarich. The vitamin attacks the Brown Pearce rabbit tumor. It has five million times the effect of xanthopterin, another compound that inhibits the same tumor.

Vitamin B_{14} was found in normal human urine. Its discovery further complicates a lively current controversy in the chemotherapy of cancer. The discussion revolves largely around folic acid, another B vitamin. A synthetic derivative of folic acid called teropterin has been reported by some investigators to ameliorate cancer, but it is not to be considered a cure. Research attention has recently shifted to certain antagonists of folic acid, notably xanthopterin and aminopterin, as possible inhibitors of human cancer.

Heroin

AN alarming increase in the use of heroin, so dangerous a narcotic that it has been completely outlawed in the U. S. for almost 40 years, is reported in a dozen countries.

In Finland, according to the international Permanent Central Opium Board, consumption of heroin in 1947 was three times what it was in 1936. For 1949, Finland has asked the Board for import licenses for thrice the 1947 amount. In Italy, per capita consumption has risen 50 per cent in a decade. Large increases have also taken place in New Zealand, Sweden and Australia. All five of these countries were criticized by the Opium Board, which is continuing the League of Nations campaign against heroin.

Heroin, a derivative of morphine, is effective in suppressing the cough reflex and was once the drug of choice in whooping cough and tuberculosis. The drug is extremely habit-forming, however, and it is now prohibited in 25 countries.

WHO on the Air

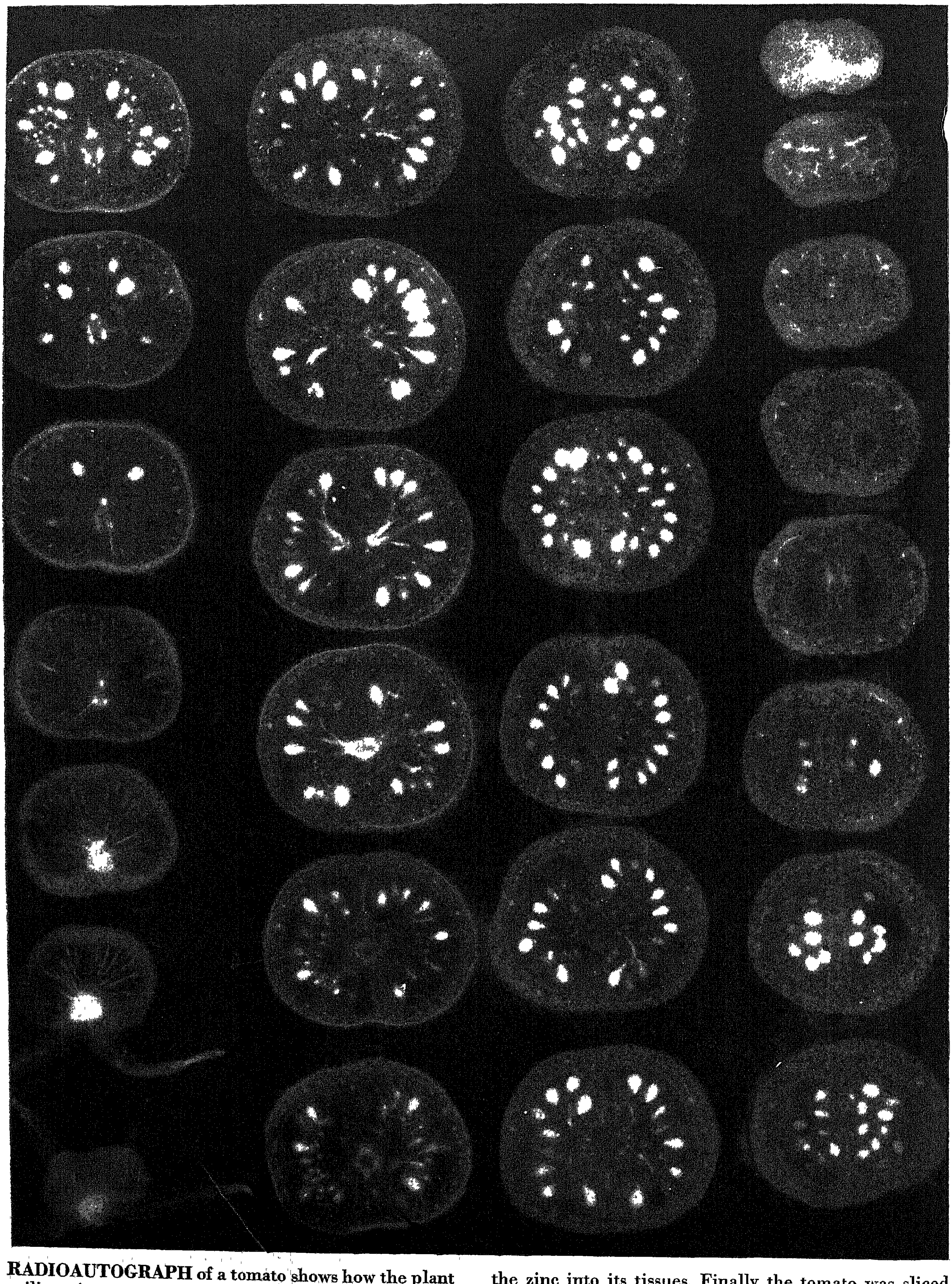
THE World Health Organization has inaugurated daily broadcasting of world-wide epidemic reports. Broadcasts are beamed to Europe, Africa and the Americas from WHO headquarters in Geneva, and to Asia from a WHO center in Singapore.

Meetings in March

OPTICAL Society of America. Winter meeting. New York City, March 10-12.

American Association of Petroleum Geologists. Annual meeting. St. Louis, March 14-17.

American Chemical Society. Semi-annual meeting. San Francisco, March 27-31.



RADIOAUTOGRAPH of a tomato shows how the plant utilizes tiny amounts of zinc. The vine from which the tomato was taken was grown in a solution containing radioactive zinc (Zn^{65}). The plant then incorporated the zinc into its tissues. Finally the tomato was sliced and placed on a photographic plate, the radioactive zinc affecting the plate just as light. Experiment was performed by Perry R. Stout of the University of California.

TRACERS

The relatively recent application of labeled atoms in biological research has already brought out some remarkable information about the chemistry of life

by Martin D. Kamen

THE recent application of isotopes as tracers for investigating life processes is now widely recognized as one of the most significant developments in the long history of the biological sciences The researches made possible by this technique already have yielded substantial contributions to fundamental biology. Beyond these, the visions opened by the technique have both surprised and stirred biologists. It is as if, looking into some quiet forest pool, one were to find its microscopic animal life suddenly endowed with visibility, revealing a vast activity of movement, interchange and transformation hardly indicated by the seeming calm and stability of the surface In much the same sense, the new-found ability to label living material with isotopic tracers has generated new insights into the ceaselessly busy system of interaction between the living cell and its environment and within the cell itself

The power of the tracer technique is readily illustrated by the simple experiment depicted on the next page. Suppose that a beaker is filled with a solution of sodium chloride—common table salt—in water, and the beaker is then divided into two compartments by means of a permeable membrane. Obviously material is diffusing back and forth through the membrane, yet no ordinary chemical or physical means can demonstrate this movement, for the system is in a state of equilibrium. The solution on both sides of the membrane is identical; each half of the beaker has the same number of positively-charged sodium ions and negatively-charged chlorine ions.

Now suppose some of the chloride is removed from compartment A and replaced with an equal volume of specially prepared chloride containing only the lighter isotope of chlorine—Cl^{35}, of atomic weight 35. Normal chlorine, a mixture of two stable isotopes, has an atomic weight of 35.5. Thus the new material, though chemically indistinguishable from the chloride it replaced, is lighter. In consequence the diffusion of the new chlorine ions into compartment B, as well as the rate of this diffusion, can be detected merely by observing the rate at which the weight of the solution in B decreases. Precisely the same result is obtained by labeling solution A with a radioactive, or unstable, isotope of chlorine instead of a stable one. The only difference is in the method of detection: in one case the diffusion is detected by weighing samples of the B solution, in the other by using an instrument to record radiation from the B solution.

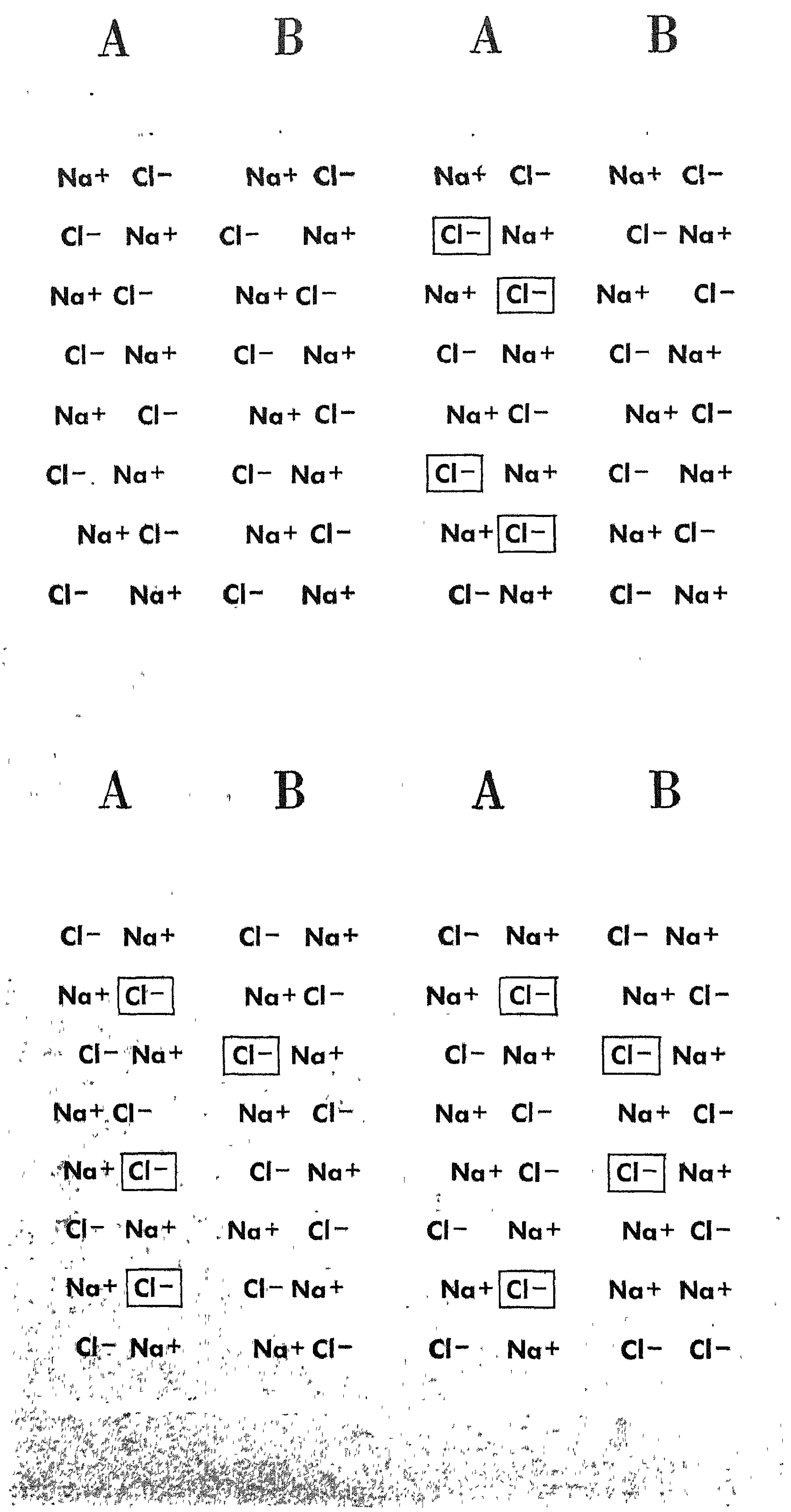
This experiment demonstrates, at the simplest level, the principle of all tracer work. The two interacting systems, A and B, may be two pieces of solid salt—in which case the membrane is the surface of contact between them—or two pieces of metal, or a cell and its surroundings, the diffusing material may be a metal, a gas, a protein, an organic product of metabolism; the membrane may be a plant surface, an animal's skin, a cell interface. In all cases the process under study is traced by labeling one of the constituent atoms of the diffusing material with an isotope and determining its fate. When, for example, the diffusing material is a labeled hormone and the membrane a cell interface, the investigator is conducting a research into the absorption and retention of hormones by a living system.

Just as in the case of the two salt solutions, isotopic tracers can be used to distinguish material entering a cell from that already present, even though no net change in the chemical composition of the cell occurs. Thus biologists for the first time are afforded a method for investigating directly the important problem of how a cell governs the uptake of material from its environment. The great sensitivity of tracer methods also makes it possible to study the exchange of material within the cell, and the constant intercourse among the agents and products of metabolism which circulate in the organism.

From Prout to Hevesy

Any account of the genesis of this fundamental advance, which thus far has been the most beneficial and useful fruit of nuclear science, must begin with the early 19th-century English physician and chemist William Prout. In 1816 he suggested that all the elements might be built of the lightest atom, hydrogen. On the Prout theory, it was expected that the atomic weight of every element would be a whole number multiple of the atomic weight of hydrogen. It turned out, however, as the weights of the elements became accurately determined, that most of them did not obey any such law. Thus chlorine, which should have had an atomic weight of 35 or 36, actually had a weight 35.5 times hydrogen. Consequently the Prout hypothesis was abandoned. It might not have been if physicists had realized that the "irreducible" elements they measured so confidently were *mixtures* of atoms, and that the atoms themselves did indeed follow the rule of integral atomic weights when compared with hydrogen.

The twin discoveries of X-rays and radioactivity in 1895 and 1896 changed the whole perspective. By means of new instruments capable of determining the properties of single atoms, it was soon found that most elements were actually families of atoms, the members of which, although chemically identical, differed from one another in certain physical properties, notably weight and stability. Chlorine, for example, was found to be a mixture of two types of atoms with weights of 35 and 37, present in the proportion of three to one respectively. Among the heavy elements were discovered a considerable number of radioactive varieties; thus a radioactive product of thorium, called Thorium C, was shown to be a member of the bismuth family, with a weight of 212



SIMPLE DEMONSTRATION of the tracer method is the case of two identical salt solutions separated by a permeable membrane. Unlabeled atoms (*upper left*) fail to show exchange across membrane. By using salt containing light isotope of chlorine (*rectangles*), the diffusion is made apparent.

instead of 209—the weight of stable bismuth atoms. It was the British physicist-chemist Frederick Soddy, a collaborator of the great Ernest Rutherford, who in 1912 gave these variant atoms of the same element the name of isotopes, from the Greek *isos* (same) and *topos* (place), meaning that they occupied the same place in the periodic table.

Once the existence of isotopes had been discovered, chemists proceeded to attempt to separate them. The experiments they devised for this purpose naturally were based on the physical differences among isotopes that resulted from their differences in mass—such as different volatility, mobility in gases and liquids, and so on. No one was more active in this type of research than a young Hungarian chemist, George Hevesy, who had come in 1913 to Rutherford's fertile laboratory at Manchester, England. In a series of researches notable for their ingenuity and precision, Hevesy and his collaborators showed that the isolation of isotopes in noticeable quantities required the most arduous kind of laboratory procedures, involving many thousands of repeated distillations or diffusions. These observations, supported by those of other researchers, indicated that in ordinary chemical processes no appreciable differences in the isotopic composition of samples of an element would be noticed until the chemical methods for determination of atomic weight approached a precision of the order of one part in 10,000 to 100,000. Thus it was established that for all practical purposes ordinary chemical manipulations would produce no change in an element's isotopic composition.

Hevesy reasoned that if one could somehow change the isotopic composition of any sample of an element, the sample could then be distinguished from the normal element. In other words, an element could be labeled by altering its isotopic content, and the labeled material could be followed through any chemical reaction. In 1923 Hevesy made his first famous tracer experiment. Because radioactive isotopes were available only in the heavy elements, he chose to begin by studying the intake of lead by plants, and he used a radioactive isotope of lead, Thorium B, to label the material. He bathed the rootlets of young plants with solutions of lead nitrate mixed with Thorium B nitrate as the tracer. After intervals ranging from one hour to two days, he burned various parts of the plants and determined the amount of Thorium B present in each part by measuring the radioactivity of its ashes.

Tools of Tracer Research

This experiment in plant nutrition was the beginning of the isotopic-tracer method in biology. The method was se-

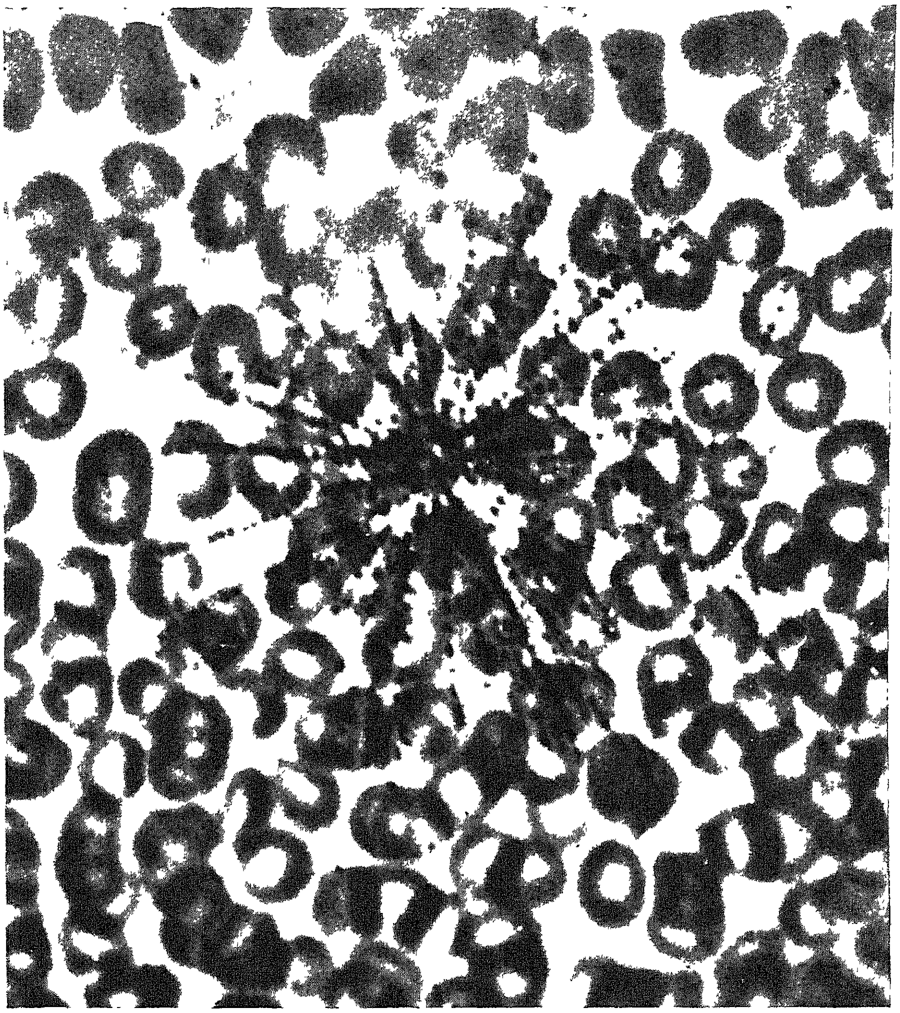
verely limited at first by the fact that all work had to be done with the heavy elements, such as lead, bismuth and mercury. No feasible method existed for the separation of stable isotopes in quantity. But the discovery of the neutron, of heavy hydrogen and of artificial radioactivity in the 1930s, and the subsequent development of large cyclotrons and atomic piles, solved these problems By the middle 1940s there was available a practically unlimited supply of radioactive isotopes of nearly all the elements. Meanwhile Harold C. Urey and his collaborators at Columbia University, in a series of remarkable researches, developed methods for bulk separation of the stable isotopes of the important biological elements.

Today tracer research is limited mainly by a shortage of trained investigators. One of the principal skills required is in the assaying of samples of labeled material, the concentration of which must be measured with precision With the development of ready-made instruments for this purpose, a tracer researcher now need not be an accomplished physicist, but considerable understanding of the physical principles involved is still necessary.

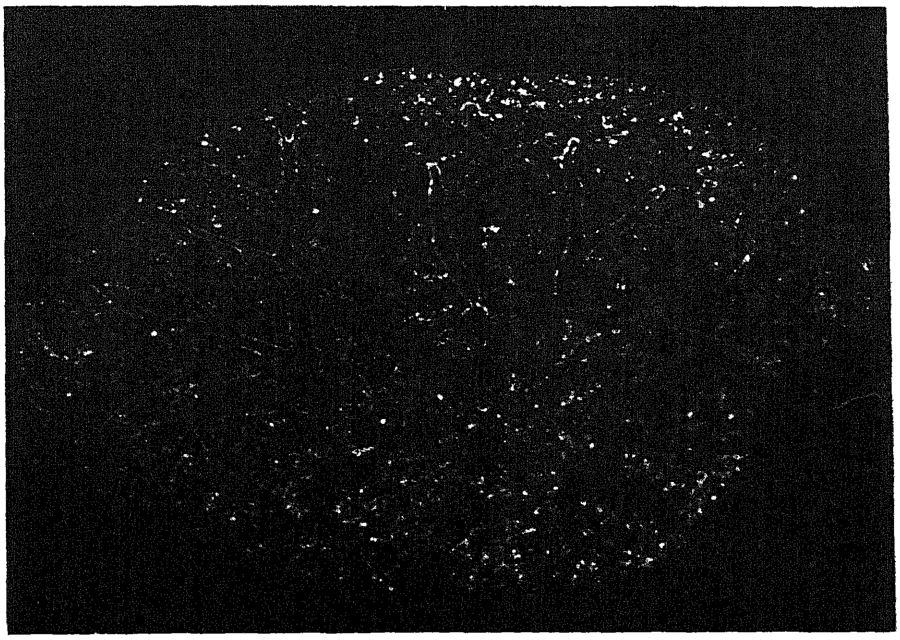
The assaying instruments are of two general types. In experiments using radioactive isotopes, the measuring instrument is the electroscope, the electrometer or the now familiar Geiger-Muller counter The latter consists essentially of an ionization chamber and an electronic apparatus which perform the functions of detecting and amplifying each radioactive disintegration of an atom, the number and rate of disintegrations is a measure of the amount of labeled material present. In experiments using stable isotopes, the measuring instrument most commonly used is the mass spectrometer, which ionizes the atoms in a sample, swings them through a magnetic field and separates the isotopes by means of their differing masses Thus the atoms of each isotope are deposited at a separate point on a collecting plate and the concentration of the labeling isotope in the sample determined.

Nature of the Problem

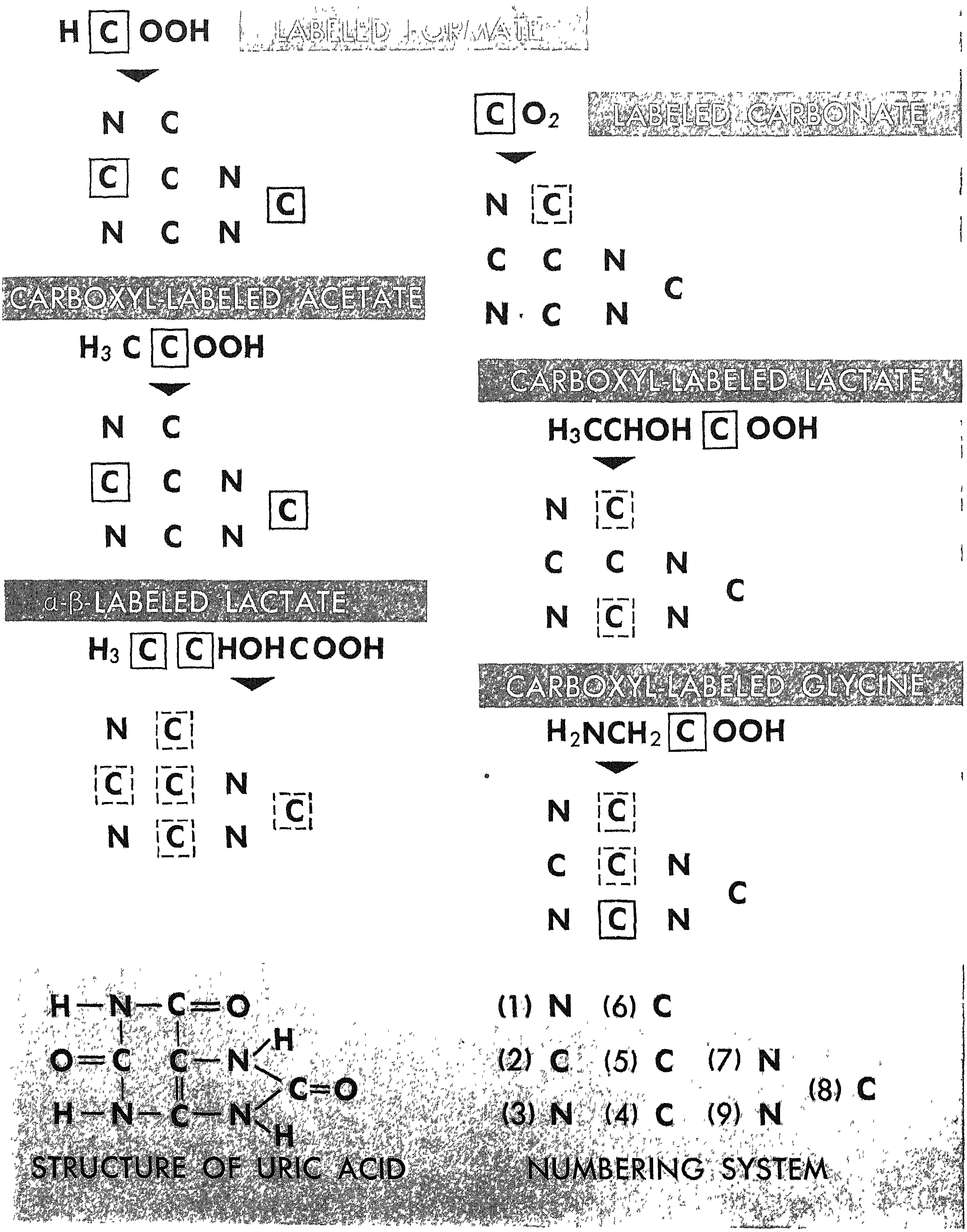
The biochemist's use of tracers is focused primarily on this basic problem: How does a given molecule play its part in the metabolism of a living organism? More specifically, what is the mechanism by which the molecule is mobilized either as a source of energy or as a contributor to the structure of living cells? In the investigation of this problem, some of the outstanding contributors have been the late Rudolph Schoenheimer and David Rittenberg of Columbia University, Harland G. Wood of Western Reserve University, and Vincent du Vigneaud of Cornell University.



BLOOD CELLS are radioautographed to locate tiny concentration of element that emits alpha particles. Here a special nuclear emulsion is placed atop cells. Cells and tracks are then photographed together. Autograph was made by George A. Boyd and Agnes I. Williams at University of Rochester.



LUNG TISSUE of a rat is radioautographed to locate inhaled plutonium oxide. The radioactive plutonium oxide is thus shown to concentrate in the rat's bronchial passageways. This study was undertaken by K. G. Scott, D. J. Axelrod, J. Crowley and J. G. Hamilton at the University of California.



CLASSIC PROBLEM was to locate source of each carbon atom in uric acid. Structure of acid is at lower left. In drawings above its hydrogen and oxygen atoms are omitted for clarity. Numbering system is used in text of article. Compounds with various carbon atoms labeled (*squares*) were fed to birds. Position of labeled atoms built into uric acid (*short arrows*) was then determined. Dotted squares indicate only traces of labeled carbon.

Their principal tools have been the stable isotopes hydrogen 2, carbon 13 and nitrogen 15.

The result of these researches may be summed up in the important general finding that a living system is a finely balanced complex of chemical reactions which, like the salt solution in the beaker, is in a continual state of flux. Metabolism is not a simple, one-way process. The substances of cells are constantly being built up and broken down from a "metabolic pool" of chemically active fragments of molecules that circulate in the organism. Schoenheimer aptly likened the adult organism to a military regiment:

"[It has] a size which fluctuates only within . . . limits, and a well-defined, highly organized structure. The individuals of which it is composed are continually changing. Men join up, are broken, and ultimately leave after varying lengths of service. The incoming and outgoing streams of men are numerically equal, but they differ in composition. . . . Recruits may be likened to the diet; their retirement and death correspond to excretion."

This analogy is admittedly incomplete; it fails, for example, to depict the chemical interaction of body constituents in the living system. Yet it remains an admirable illustration of the meaning of the "dynamic state" in biology.

The tracing of a metabolic process, as already indicated, involves two basic steps: 1) labeling a food or another substance fed to the organism, and 2) analyzing the intermediate and ultimate products that may be formed from this substance to determine the amount, if any, of the tracer isotope present. In biological research it is often preferable to use a stable isotope rather than a radioactive one, to avoid the danger of damaging the organism by radiation effects. Thus the use of radioactive carbon 14, for example, has not been considered advisable in studies of human beings; it has a half life of 5,100 years and would continue to radiate throughout the subject's lifetime wherever it remained in the system.

The labeling process itself is merely a matter of chemical preparation. The compound to be fed to the organism is synthesized chemically in the usual way; the only difference is that for one of the components in the molecule a single isotope, or an unusual proportion of that isotope, is used instead of the natural element. Thus if the atom to be labeled is nitrogen, the compound is prepared with nitrogen 15. Supplies of separated isotopes are now available commercially or from an institutional laboratory.

The tracing of the labeled material, however, is somewhat less simple than a game of hare and hounds. The labeled compound must be prepared in such a way that the label is not lost, either because of excessive dilution in the pool of the same material that is already present in the organism, or because of interference by biochemical processes not connected with the one being studied. Moreover, the success of the experiment often depends on an accurate estimate of how thoroughly the labeled compound mixes with the same material in the organism, if the mixing is incomplete, it becomes difficult to judge the significance of the concentration of labeled material finally found in the cells where it is used. A further difficulty enters with regard to the purity of the sample, in tracing the intermediate steps in metabolism it is usually no simple problem to isolate the molecules carrying the label in a state that is sufficiently pure to permit an unambiguous analysis of the meaning of their labeled content.

Precursors and Products

Let us consider now a classic example of tracer research. This study, of the type known as "precursor-product" research, in which it is shown that a certain compound, B, is derived from a precursor compound A, was conducted by John C. Sonne, John M. Buchanan and Adelaide M. Delluva at the University of Pennsylvania Medical School. It was designed to determine the sources of the various carbon atoms found in uric acid, a product of the breakdown of protein in birds, snakes, lizards and invertebrates. The structure of uric acid is shown at the bottom of the diagram on the opposite page. Each atom is numbered for identification according to its position in the molecule. The objective of the experiment was to learn the respective origins of the carbons numbered 2, 4, 5, 6 and 8.

The investigators used pigeons as the test animal. They fed or injected into a group of birds several simple carbon compounds which might be the original sources employed by the pigeons to synthesize uric acid. These compounds were labeled with carbon 13 in various ways. Thus one of the compounds, lactic acid, which has the formula $H_3CCHOHCOOH$, had three carbons available for labeling, the carbon 13 atom could be placed in the carboxyl group (COOH) or in the first two positions, the so-called alpha and beta carbons.

After the birds had been fed these compounds for a day or two, uric acid was recovered from their excretions. It was then purified and analyzed for the presence of carbon 13 in the various fractions of the uric acid molecule, the fractions being obtained by a controlled chemical breakdown of the compound. Each fraction identified the position of one of the carbon atoms in the uric acid molecule; carbon in the sixth position, carbon-6, for example, was split off the molecule in a carbon dioxide fraction.

The results of the experiments are pictured in the schematic diagrams on the opposite page. They show the positions in the uric acid molecule at which tracer carbon from each of the precursor compounds finally arrived. In the terms of Schoenheimer's regiment analogy, the compound fed to a pigeon may be considered a group of recruits, each of whom is destined to wind up in a specific suitable job, depending on his place of origin. The recruits corresponding to the atoms in the compound acetate (H_3CCOOH), let us say, all come from Texas; those corresponding to the carbon atom in the carboxyl fraction of acetate (COOH) are all from the city of Houston. To keep track of these men and maintain the regimental records in proper shape, the Houston recruits are labeled for identification. When soldiers finish their term of duty in the regiment, they are mustered out by groups (in this case representing molecules of uric acid). It turns out that when the departing groups are examined, the labeled Houston recruits in them appear in one of two jobs: they are all either riflemen or bazooka specialists.

Similarly, when a pigeon is fed carboxyl-labeled acetate, the labeled carbon invariably appears in uric acid as carbon-2 and carbon-8. When a pigeon is fed formate (formic acid), the labeled carbon from that compound also appears in uric acid as carbon-2 and carbon-8—not all riflemen and bazooka specialists come from Houston. On the other hand, carboxyl carbon does not always appear in the same positions; the carboxyl carbon derived from the amino acid glycine, for example, becomes carbon-4 in uric acid. It is as if the fate of each recruit depends not only on the type of city but also on the state from which he comes. Thus the most important basic finding developed by this research is that the compounds fed to a living organism are all used in different ways.

Measurements of the tracer carbon in uric acid established that carbons-2 and -8 could be derived from formate or from the carboxyl group of acetate, that carbons-4 and -5 could be contributed by the amino acid glycine, that carbon-6 came mainly from carbon dioxide but was also derived in small amounts from other compounds.

Yet so intricate is the mechanism of metabolism that the appearance of a tracer isotope in the final product may be deceptive. For example, all compounds labeled with tracer carbon in the carboxyl group are subject to breakdown in the body, yielding labeled carbon dioxide. As a result, when the labeled carbon is found in a later product it is difficult to tell whether the product's carbon is normally derived from the original compound or from carbon dioxide.

Often the solution of the problem requires close attention to the time factor in the diffusion of the isotope

The Red Cells

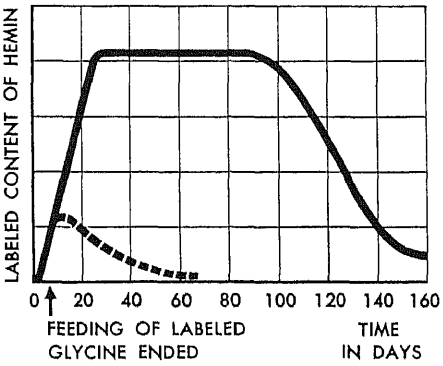
An outstanding example of this type of research was a series of experiments recently conducted by David Shemin and David Rittenberg at Columbia University. They were studying the manufacture of hemin by the human body. Hemin is the iron-containing blood pigment that combines with globin, a protein, to form hemoglobin, the substance that transports oxygen in the blood. The researchers had established that in the rat the nitrogen of hemin is derived mainly from the amino acid glycine (NH_2CH_2COOH). To trace the process in a human subject, they labeled glycine with nitrogen 15 and fed small amounts of the compound (a total of one and one-half ounces) to the subject for three days. Then at regular intervals they obtained from the subject samples of a hemin derivative called protoporphyrin and examined it for evidence of the tracer nitrogen.

Now the result one would normally have expected, in view of what was known about the dynamics of metabolism in general, is somewhat as follows: The labeled glycine would mix with the glycine already present in the circulation and within a relatively short time would become available for incorporation into the new hemin constantly being produced in the body. As new red cells were formed, labeled hemin would appear in the circulating blood. Meanwhile, unlabeled hemin would be removed from the blood as older red cells were destroyed. Thus the proportion of labeled hemin in the blood would increase steadily as long as labeled glycine was fed. Shortly after the subject returned to a normal diet containing unlabeled glycine, the situation would be reversed. Now unlabeled nitrogen would be coming into the hemin and labeled nitrogen would be going out. If the red cells were constantly exchanging material with their surroundings—a condition characteristic of practically all metabolic processes—the proportion of labeled hemin would soon start to drop. The curve recording the abundance of labeled hemin in the blood during the course of the experiment would follow a certain familiar pattern: it should rise sharply at first, level off for a brief period, and then decline.

The actual result was quite different. After the feeding of labeled glycine was stopped on the third day, the concentration of labeled hemin did not level off but continued to increase for nearly 25 days! Then it became stabilized for a long period. Not until the 100th day did the concentration begin to drop.

The deduction to be drawn from these facts was clear. It appeared that hemin, unlike other active tissue, was comparatively stable. Instead of being continually broken down and rebuilt, red cells, like human beings, evidently have a definite average lifetime during which they remain intact. Normally they are destroyed or die only after reaching a certain age. The observations indicated that the average human red cell has a life span of about 130 days. The new red cells that were formed while labeled glycine was available retained the label until they died, and the labeled nitrogen then released was not used again in the manufacture of hemin.

Obviously this finding has considerable significance to medical science.



HEMIN, a constituent of hemoglobin, was found when labeled to remain in the blood for relatively long period. Predicted curve is at left.

Tracer nitrogen can be used to study the life span and destruction of hemin and red cells in various types of human blood disorders. Such researches have already begun and they have a bright future.

A Tracer Study

Recently the writer participated in a related study that illustrates even more vividly the complex trail which sometimes must be followed in tracer research. Moises Grinstein, an Argentine biochemist working as a visiting fellow in the hematology laboratories headed by Carl V. Moore at the Washington University Medical School, consulted the writer on the feasibility of using tracer techniques to study certain problems in blood chemistry The problem first presented was to identify the precursors of a close chemical relative of hemin known as Coproporphyrin I, a substance found in human excreta. The chemical structure of this substance, like that of hemin, is based on the so-called "pyrrole" rings, which in turn are linked together to form the "porphyrin" ring pictured at the right.

The plan of investigation eventually decided upon was to try to build up a supply of labeled hemin in a dog, transfuse the labeled blood into a second dog and find out whether the labeled hemin yielded labeled Coproporphyrin I when it was degraded (*i.e.*, broken down) The purpose of this research was to determine whether hemin was a precursor of Coproporphyrin I and hence possibly of other blood pigments. The particular part of the molecule to be studied was the porphyrin ring, common to hemin and other blood pigments. And the element to be traced was carbon. Shemin and Rittenberg had shown that glycine could supply the nitrogen in hemin. Could the same compound also supply hemin's carbon? Some researchers indeed had suggested that the whole glycine molecule might enter into the synthesis of the porphyrin ring.

The first problem then was to obtain some carbon-labeled glycine. There were two carbons in the molecule available for labeling: one in the carboxyl group (COOH), the other in the "methylamino" group (NH_2CH_2). Since it was assumed that both carbons of glycine were used in the synthesis of hemin, it appeared immaterial which one was labeled. We decided to use carboxyl-labeled glycine because supplies of this material were readily available.

One hundred milligrams (about 3.5 thousandths of an ounce) of glycine labeled with the radioactive isotope carbon 14 in the carboxyl position were obtained from R. B. Loftfield of the Massachusetts Institute of Technology. The total radioactivity of this material was five million times the lower limit of detection (LLD) of our assay instrument—a special type of Geiger-Müller counter that is particularly responsive to the radiations characteristic of carbon 14. Calculations based on this activity and on the assumed uptake of carbon by the blood indicated just how much radioactivity we should expect in labeled blood samples recovered from a normal dog. the radioactivity should be 100 LLD in every milligram of hemin, and, assuming that labeled carbon also entered the globin part of the hemoglobin molecule, 10 LLD in every milligram of globin.

The dog was first bled so that it would take up a maximum amount of labeled glycine as it replenished its blood supply during the feeding period. The labeled glycine was given by stomach tube in three feedings over a period of three days. The dog's blood supply rapidly returned to normal and the animal appeared contented. Samples of its blood were drawn on the 11th, 14th, 20th, 37th and 52nd days after the glycine was administered. The blood was then separated into hemin and globin fractions. Each of these fractions was purified and assayed for radioactivity.

Contrary to expectations, the assays showed that no radioactivity whatever appeared in the hemin. Thus our assumption was proved incorrect: the car-

boxyl carbon of glycine was not used in the synthesis of hemin. We had chosen the wrong carbon for labeling, for it developed later that the other carbon atom in glycine, the one in the methylamino group, did enter into hemin.

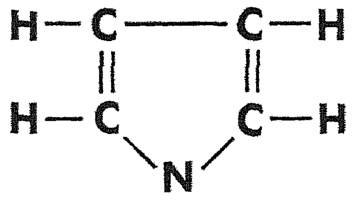
The globin fraction, on the other hand, exhibited the expected amount of radioactivity, indicating that it had used some of the carboxyl carbon from glycine. And here it developed that the labeled globin followed the same kind of time schedule as the labeled hemin in Shemin and Rittenberg's experiment. The curve of abundance of labeled material was exactly the same, except that it began to decline a little sooner, indicating that the life span of this particular dog's red cells was 100 days, instead of 130 days as in man. Evidently the globin part of the hemoglobin molecule, like the hemin part, did not participate in the dynamic flux of body metabolites but maintained its integrity during its lifetime.

The general conclusion from this research was that the glycine molecule was not taken *in toto* into the porphyrin ring of hemin, as had been suggested. Its carboxyl carbon was lost to other metabolic processes, including the manufacture of globin. The nitrogen and carbon from the methylamino part of the glycine molecule *were* used in the synthesis of hemin, and it was established that they entered into hemin's pyrrole rings, as shown in the diagram on this page. It could be seen that to carry out the original purpose of the research, *i.e.*, the study of the possible role of hemin as a precursor for other blood pigments, a fresh start would have to be made with glycine labeled with carbon 14 or nitrogen 15 in the methylamino group. Such experiments have been performed recently and indicate that Coproporphyrin I is not derived from blood hemin but is formed in all likelihood from a precursor common to both hemin and Coproporphyrin.

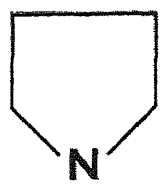
This account, incidentally, illustrates not only the many kinds of techniques required in a single tracer experiment but the healthy erasure of boundaries in biological science. To carry through this experiment required at least three specialists, a hematologist, a biochemist and a physical chemist.

The Versatility of Tracers

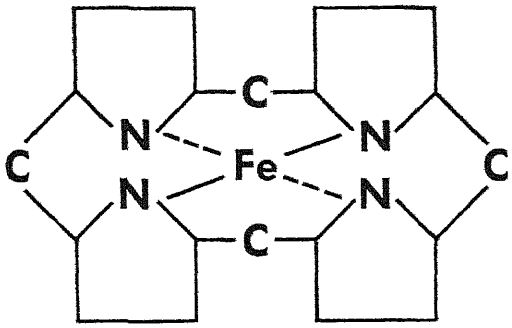
It must not be supposed that precursor-product researches are the most important type of investigation accessible to tracer techniques. They are only one aspect of the central problem in biochemistry: the elucidation of the mechanisms by which the body regulates and integrates its constant breakdown and synthesis of materials. In any given biochemical process, an important role is played by linked chains of reacting



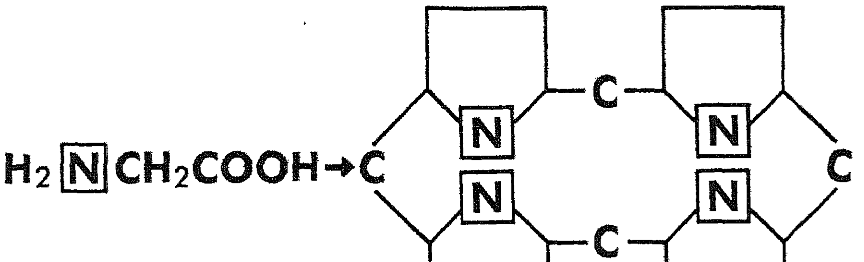
PYRROLE RING



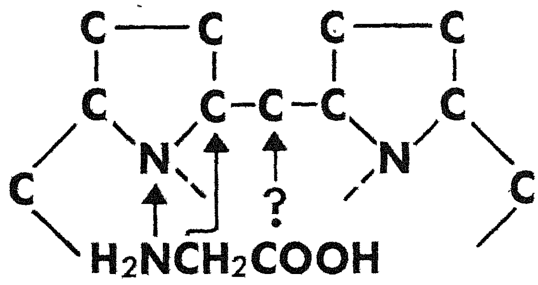
SYMBOL OF PYRROLE RING



INTERNAL RING STRUCTURE OF HEMIN

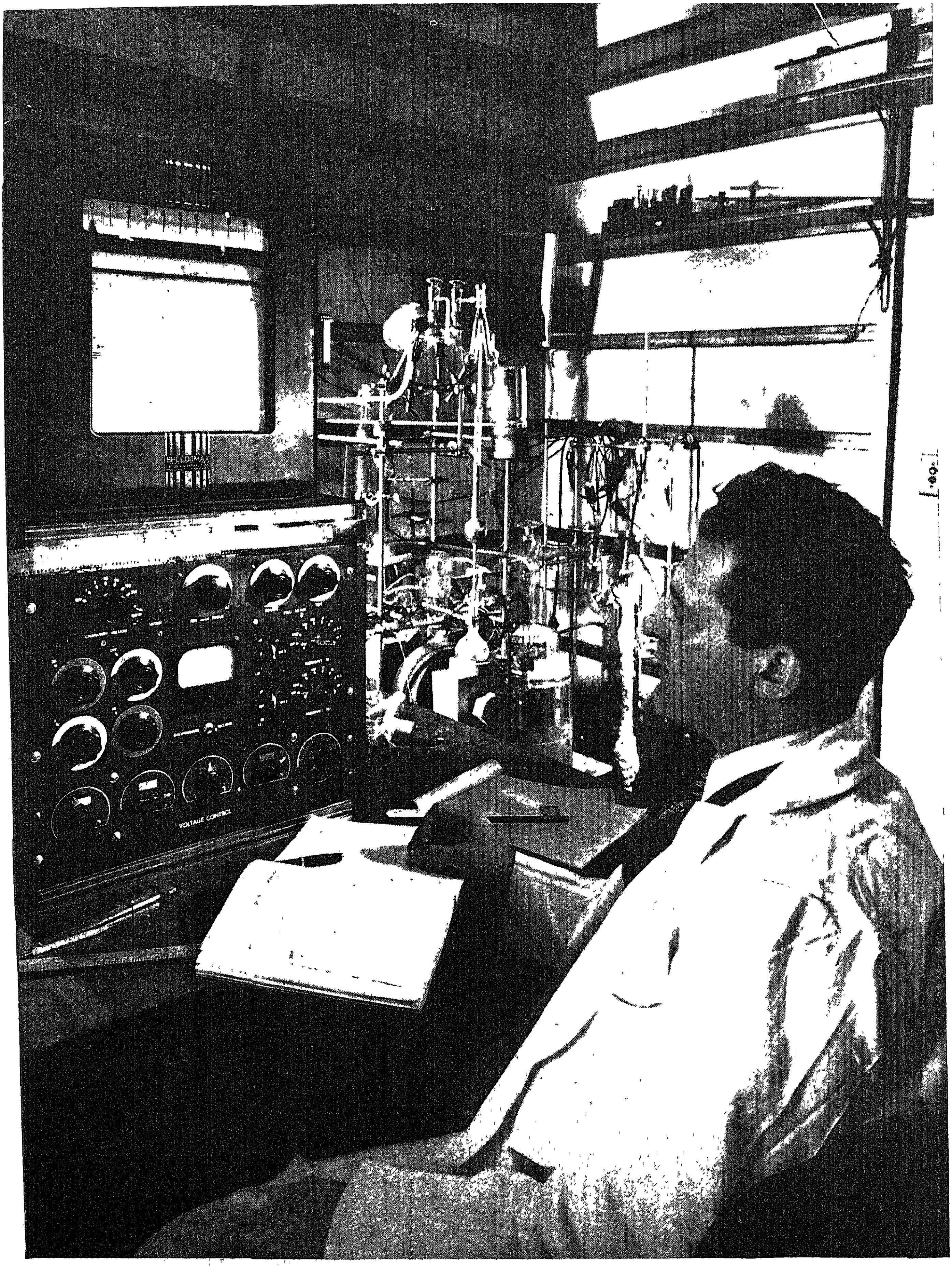


GLYCINE



GLYCINE

LABELED NITROGEN was used in experiments to determine the source of the element in hemin. At top is the structure of the pyrrole ring, four of which enter into the structure of hemin. Labeled nitrogen in glycine was built into rings. Source of linking carbon (*question mark*) is unknown.



MASS SPECTROMETER at Columbia University's College of Physicians and Surgeons is employed in tracer research to measure the relative concentration of non-radioactive isotopes of hydrogen or nitrogen. The spectrometer itself is in the background. Engineer Irving Sucher sits before the controls and recording devices.

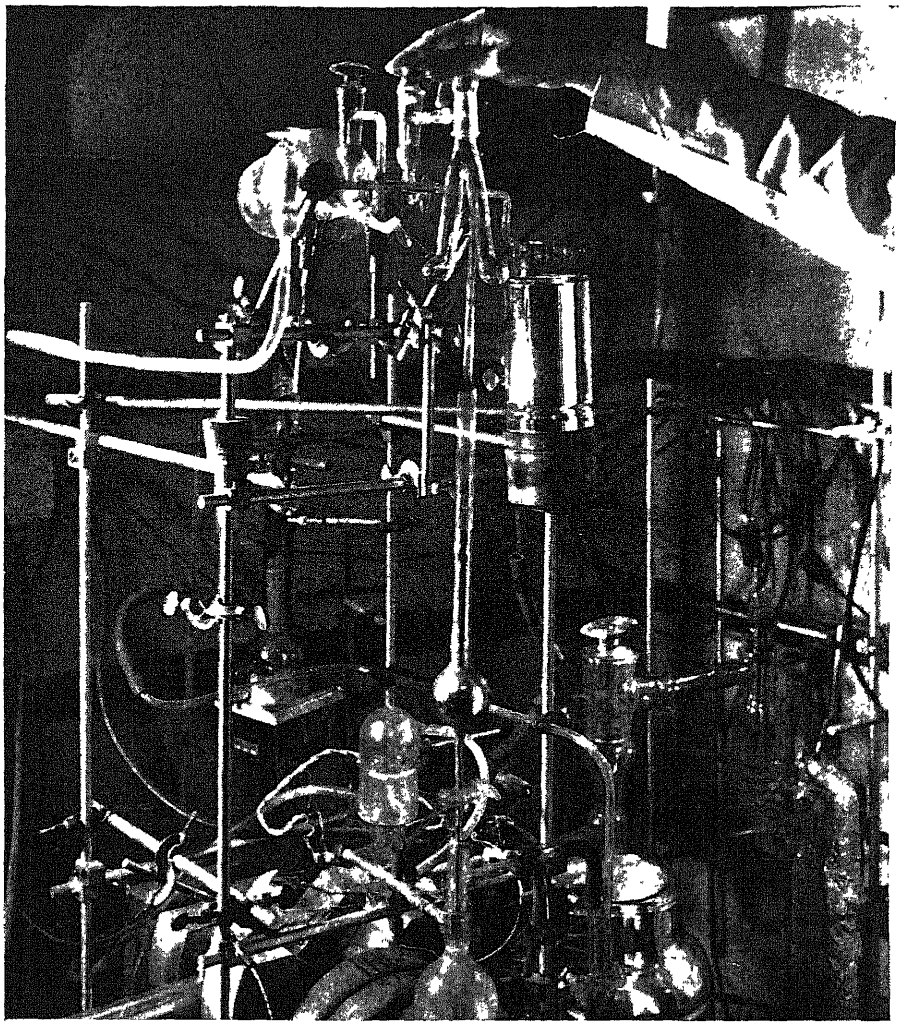
agents which act as intermediates in accepting and passing along certain necessary atomic fragments supplied by material taken into the body. Each step in such a process is controlled in general by an enzyme. All enzymes appear to be proteins. The entire process is self-contained and self-regenerating: it proceeds in a cyclic fashion. The tracer approach is particularly useful in ferreting out possible intermediates and participating molecules that are not obviously involved or are not observable by conventional chemical methods alone.

This is not to say that conventional chemistry has not developed a great deal of information about metabolism. But tracer methods permit much more latitude in such studies and yield more certain results. One of the most important facts it has established, a fact which could never have been determined by conventional methods, is the importance of carbon dioxide in metabolism. Carbon dioxide, once thought to be simply a waste product, has been found to enter into an astonishing diversity of processes in the animal organism.

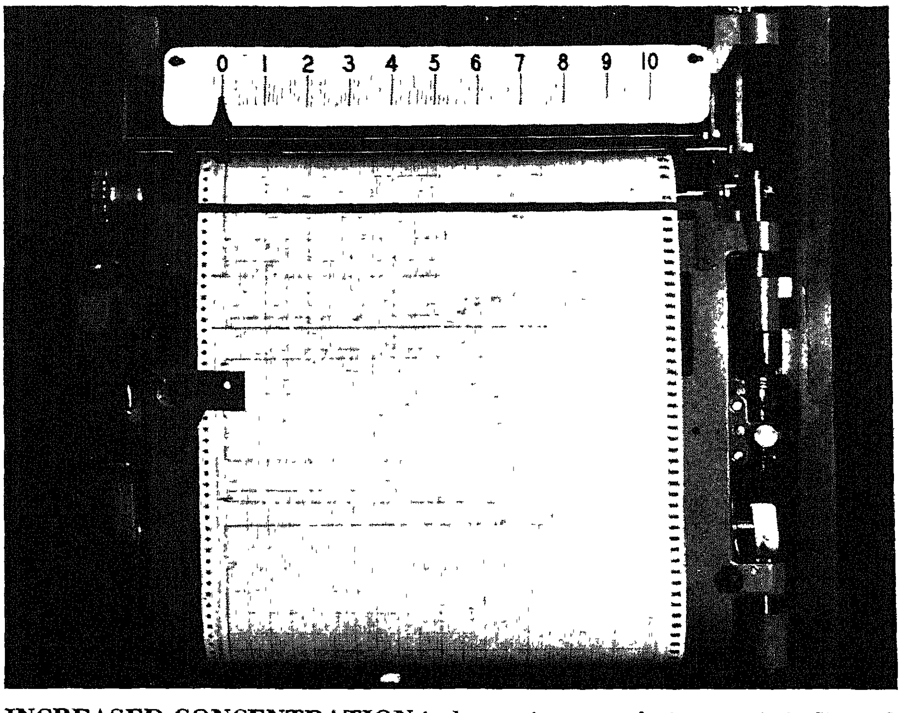
Another problem in which tracers are helpful is the study of living material in an artificial environment. Biochemists often are compelled to investigate the reactions that take place in cells under test-tube conditions outside the living organism. In the test tube most such partial systems rapidly tend to a state of equilibrium. In the living organism, however, they are not at equilibrium but interact with their surroundings. Thus a test-tube study usually cannot determine how such a system functions in its normal environment.

As an example consider the problem of the formation of protein. Proteins are built up in some as yet unknown way from simple amino acids. This process, as well as the breakdown of proteins into amino acids, is controlled by enzymes. In the living cell, the synthesis and degradation of protein is balanced. But when the protein-metabolizing system is extracted from the cell, the regulating mechanism is damaged or entirely destroyed. Now breakdown begins to predominate over synthesis, because the energy relations favor the destruction of protein. Under those conditions the synthesis reactions cannot be followed chemically.

Such a study becomes possible, however, with the aid of tracers. As soon as the cellular extract is isolated from the organism, a labeled amino acid such as glycine is added to the extract. If any synthesis of protein takes place, the labeled amino acid will be taken up, along with other amino acids made available by the breakdown of protein molecules. If there is any appreciable reversibility in the system, *i.e.*, recombination of the amino acids from broken protein to form new protein molecules, the pro-



SAMPLE IS INSERTED into spectrometer in Y-shaped tube (*beneath technician's hand*). Sample is in one side of tube: sodium hypobromite is in the other. When the two are mixed, nitrogen is released and analyzed.



INCREASED CONCENTRATION in heavy isotope of nitrogen is indicated by recording apparatus. Scale of peaks is shifted for convenience. Two peaks below show natural concentration. Peaks at top show increase in nitrogen 15.

tem will have an increasingly greater labeled content as new molecules are synthesized. At some arbitrary point, say when half of the protein has disappeared, the reaction is stopped and intact protein is removed for assay of the amount of tracer in it.

This procedure makes it possible in most cases to determine whether a particular system is reversible enough to be of any importance in the synthesis of cellular protein. Furthermore, it permits the detection of protein synthesis in systems where it cannot be discovered by any other means. The technique can be applied, of course, to a huge variety of biochemical problems.

The great subtlety of the tracer approach is well illustrated by still another technique. Sometimes the biochemical product being studied does not exist in the organism in sufficient quantity to be isolated or analyzed In such cases some of the product is added to the labeled precursor when the latter is fed to an organism. This unlabeled "carrier" material adds to the body's supply of the product; it is fed in a quantity sufficient to permit analysis of the product, but not too great to dilute the label beyond detection.

The mixing of labeled with unlabeled material is extremely useful in analytical biochemistry. Suppose, for example, one desires to ascertain whether a given compound is present in a cell extract; let us say the problem is to determine the percentage of glycine present in a mixture obtained by hydrolysis (breakdown by water) of a cell protein. This is a formidable problem by conventional chemical methods, for complete recovery of the glycine in a pure state is required and amino acids are not easy to separate from one another.

The tracer method solves it easily. We add to the extract a carefully measured quantity of labeled glycine. The labeled sample mixes with the glycine in the extract. Now we can measure the amount of glycine originally present by measuring the dilution of the label, which depends only on the relative amounts of the original glycine and the labeled addition. Suppose, for example, we add 10 milligrams of glycine containing 10 units of labeled carbon to one gram of the original protein containing an unknown amount of glycine. We now isolate and purify a small sample, say one milligram, of the mixture of labeled and unlabeled glycine, and measure the concentration of labeled carbon in it. We find that the concentration is one half of one unit. In the labeled glycine that was added the concentration was one unit per milligram. Thus it is clear that the added glycine doubled the amount originally present, which means that the extract contained 10 milligrams of glycine. Here, then, is a method of analyzing any compound for one of its components without separating out all of the component in a pure state: we need only measure the labeled content of a known amount of added material and the labeled content of a purified sample of the combined mixture, a simple formula then gives the amount of the component being measured. This method is being developed with many variations as one of the most useful analytical tests in biochemistry

New Frontiers

These examples suggest, but by no means completely define, the immense new frontiers opened by the isotopes in biochemistry. And biochemistry is only one of the fields of application for tracers. Their usefulness is equally impressive in physiology. The biochemist is concerned primarily with isolated enzyme systems and with what goes on in the cell. The physiologist is concerned with interactions between enzyme systems and with the economy of the cells as a whole. Because the cells, in contrast to their ever-changing constituents, are more or less in equilibrium with their environment, tracers are indispensable to the study of the two-way traffic that goes on across cell membranes. They are an invaluable means for investigating the permeability of membranes, the accumulation of metabolites at specific spots in the cell, the transportation of substances to various destinations in the organism.

By the use of tracers it has been learned that the liver is primarily responsible for the manufacture of phospholipid (a fatty phosphorus compound) in blood plasma, and that thyroxine, the iodine-containing amino acid that is so important in the functioning of the thyroid, can be manufactured by muscle and intestine. Tracer studies have also yielded considerable information about the absorption of iron in mammals. This absorption appears to be regulated by the amount of reserve iron in the body, particularly in the mucous membrane of intestine. From tracer investigations it has been deduced that iron in food enters the gastrointestinal system in its higher oxidation state, is reduced in the jejunum to its lower oxidation state and then is absorbed in the intestinal mucosa, where it combines with a protein to synthesize an iron-containing protein called ferritin and is stored in that form. Regulation of the absorption of iron from food by the organism depends on an equilibrium between oxidized iron in blood serum and reduced iron and ferritin in the mucosa.

Another important tracer research has confirmed certain speculations on the nature of the process of fermentation of carbohydrates in cells; it has shown that the major pathway for such fermentation is a reaction cycle in which carbohydrate combines with phosphate to form certain specific intermediates.

An inquiry in which tracers have been especially helpful is the investigation of the biological role of elements that living cells use in vanishingly small amounts, such as boron, molybdenum, manganese, copper, and so on. The functions of these elements have been little understood, for biologists have lacked reliable techniques for studying them. By the use of labeled samples which make it possible to detect microscopic amounts of these materials, research workers have now begun to develop considerable data on their absorption, retention and excretion by the organism.

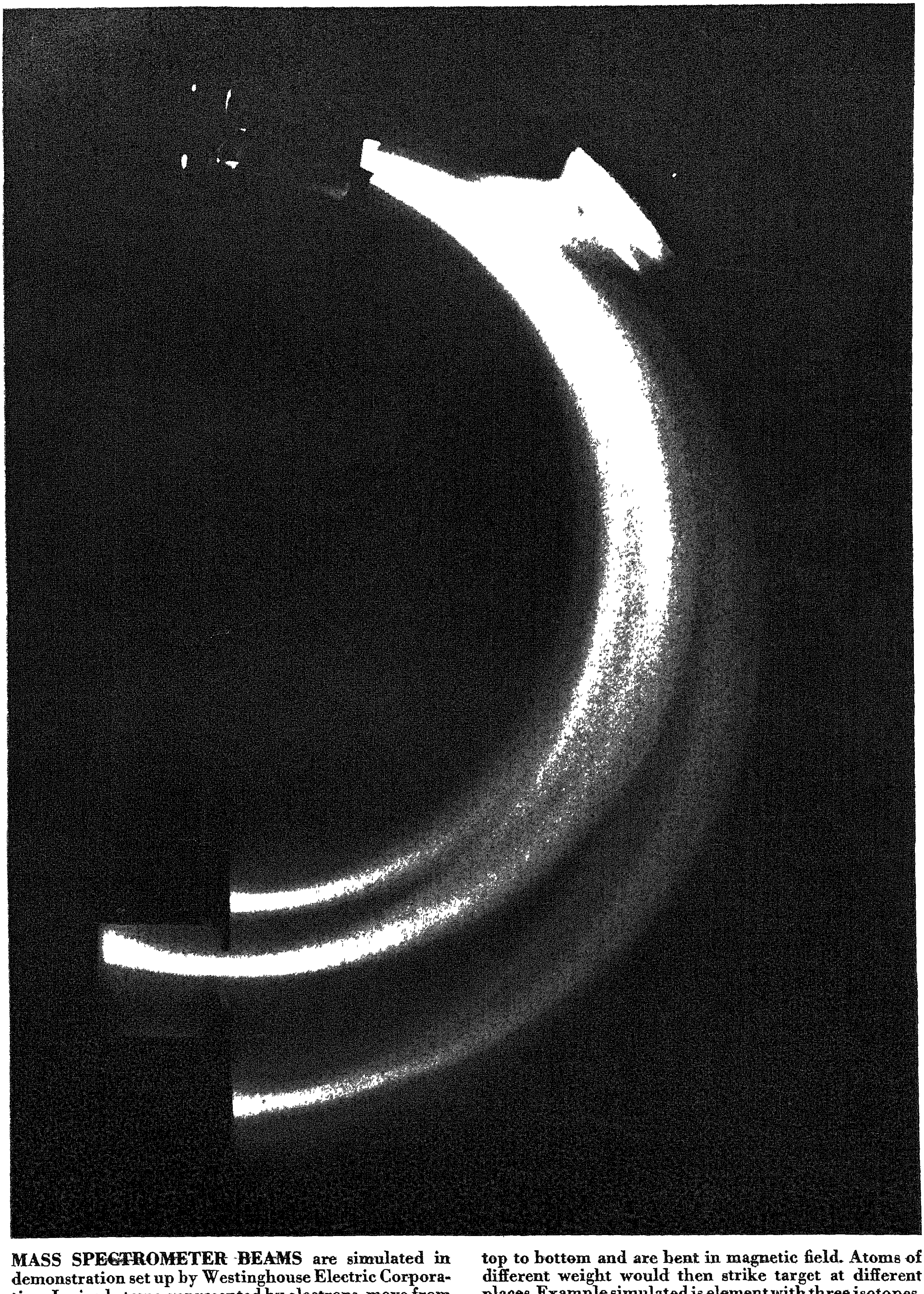
Medical Studies

In medicine, the application of the tracer method is still only in its infancy, but much has already been done. The use of radioactive isotopes in treating certain blood disorders and some cancers is now routine. Radioactive phosphate has been shown to have definite advantages over X-rays in the treatment of polycythemia vera, a disease of the red blood cells, and of some types of leukemia, the cancerlike blood disorder. Radio-iodine is becoming a popular prescription for the control of hyperthyroidism.

In medical research, tracer studies have already made several invaluable contributions. Investigations with tracer iron of the conditions for survival of human red cells have improved the method of storing blood for transfusions. Tracers have made possible accurate measurements of the blood volume in the body under a variety of conditions, ranging from the normal condition to that of patients in extreme shock. They have permitted studies of disturbances in iron physiology that attend pregnancy. They have shed light on the dynamics of inflammation; tracers may even make it possible to locate internal sites of inflammation in the circulatory system without recourse to surgery. Labeled sodium has been used to diagnose disturbances of circulation in the small peripheral blood vessels, and to test the value of various drugs used to dilate or open the vessels.

Valuable as these direct medical harvests are, it seems clear that the most profound results of tracer research in the coming years will be achieved at the fundamental level of biochemistry and physiology. Even the most cautious observers agree that this research promises incalculable benefits to mankind.

Martin Kamen is associate professor of chemistry at the Washington University School of Medicine.



MASS SPECTROMETER BEAMS are simulated in demonstration set up by Westinghouse Electric Corporation. Ionized atoms, represented by electrons, move from top to bottom and are bent in magnetic field. Atoms of different weight would then strike target at different places. Example simulated is element with three isotopes.

MICROSEISMS

Tiny waves that do not originate with earthquakes have puzzled seismologists. Some have been traced to storms, but this does not tell the whole story

by L. Don Leet

SEISMOGRAPHS have been in continuous operation in various parts of the world for over 50 years. Thus we now have a long-term record of the earth's shakings and quiverings. At first the purpose of these observations was the study of waves from earthquakes, but the instruments were found to be recording waves from many other sources as well. Spiders, vagrant air currents in recording vaults, distant railroad trains, and depth bombs exploded during the war have made their contributions. The most remarkable and puzzling of these non-earthquake disturbances have been the waves known as microseisms.

These small tremors, which range in period from a fraction of a second to 10 seconds, are recorded in all parts of the world: in the middle of continents, on continental shores, on islands in mid-ocean. Present at all times in varying degree, the microseisms occasionally increase to relatively large amplitudes for hours or days at a time; these intervals are called microseismic storms.

The tiny waves have been an object of intense speculation among seismologists ever since seismographic recording began. One of the chief reasons that they still remain an unsolved mystery is the peculiar pattern of wave motion they produce. The pattern of waves from an earthquake is systematic. It spreads out and changes with distance, but does so in a regular manner. A given group of waves can be recognized at neighboring stations and at equal distances in different directions; it can even be traced for thousands of miles in some instances. However complicated earthquake waves may become at great distances, they can always be traced back to a fixed source in some limited region—practically a point in terms of global dimensions.

This is not true of microseismic waves. They produce a unique pattern at each station. At a single station they record in groups that suggest patterns of wave interference, and these groups usually cannot be correlated at stations only a few miles apart. The natural conclusion from this universal observation is that microseisms come from a multiplicity of sources and represent groups of waves crisscrossing the crust of the earth from several directions.

This characteristic, which left seismologists with no good toe hold on the problem of where the microseisms originated, delayed even the collection of direct data for over half a century. As a microseismic storm develops, it often produces practically simultaneous increases in wave amplitudes at stations spread over half a continent. Attempts have been made to locate the source by plotting on a map contours along which the microseismic waves at various stations are of equal amplitude. But these efforts have never succeeded in pinning down the source in any definite fashion. The closest they have come is to suggest that in most cases the disturbance originates in some large body of water, such as a region of an ocean.

Attention was early directed to the fact that in many cases there appeared to be some correlation between microseismic storms and atmospheric storms. The first plausible hypothesis was proposed in 1904 by E. Wiechert of Gottingen, Germany, who suggested that microseisms were caused by the beating of surf on rocky coasts. The German seismologist F. Linke in 1903 used microseisms to predict the approach of storms in the vicinity of Apia, Samoa. Support for Wiechert's theory was offered by Beno Gutenberg of Gottingen on the basis of investigations in Europe. In 1931 Gutenberg published the results of a similar study for North America. His summary, which was widely accepted as the final word on the subject, asserted.

"So we find that, just as in Europe, surf due to storm against steep, rocky coasts is the cause of the microseisms with periods of four to nine seconds. . . . Observations show that neither the air pressure, nor its change, nor storm can be the cause of the microseisms. The result of calculations is that no possible disturbance near the surface of the ocean can be propagated through the water to the bottom, but that the energy of the waves transferred by the surf to the coast is large enough to cause the movements."

The study of microseisms entered a new phase with the development of methods for determining the direction in which they travel. The basis of these methods was a triangular system of recording stations. Back in 1884, John Milne, a British physicist who became one of the founders of modern seismology while teaching in Japan, had set up seismographs at the corners of a triangle on the campus of the Tokyo Engineering College. He supplied them with a circuit for simultaneous time marks at all three stations, and he endeavored to determine the direction of travel of earthquake waves crossing the network. The first experiments were not satisfactory because the stations were too close, but Japanese seismologists later got better results by enlarging the triangle, the distance between stations ranging from 7,500 to 35,750 feet. By selecting a wave that could be recognized at all stations of the network, and measuring the time of passage of the same phase of that wave at each station, these investigators determined the direction of approach for waves from a number of earthquakes.

THIS method was first applied to the study of microseisms in 1927 by F. Kishinouye and N. Nasu of the University of Tokyo. They used three portable seismographs spaced from 1,400 to 3,600 feet apart. They were able to recognize certain groups of microseisms at all the stations, but decided the phase relationships indicated that the waves were "a kind of free oscillation" of a block of the earth separated by fissures from its surroundings, *i.e.*, that the oscillations were of the type known as stationary waves. These observations were admittedly inconclusive, for the seismographs used recorded only the north-south component of the waves. When Kishinouye later analyzed other components, however, he did not change his conclusion that the microseisms were stationary waves.

The research was pursued further in 1936 at Göttingen. There H. D. Krug set out two portable stations which, with a central station, defined a triangle with sides approximately 4,500 feet long. Such an array is now called a tripartite network, or station. With these, he was able to trace some of the microseismic wave groups across his network and to

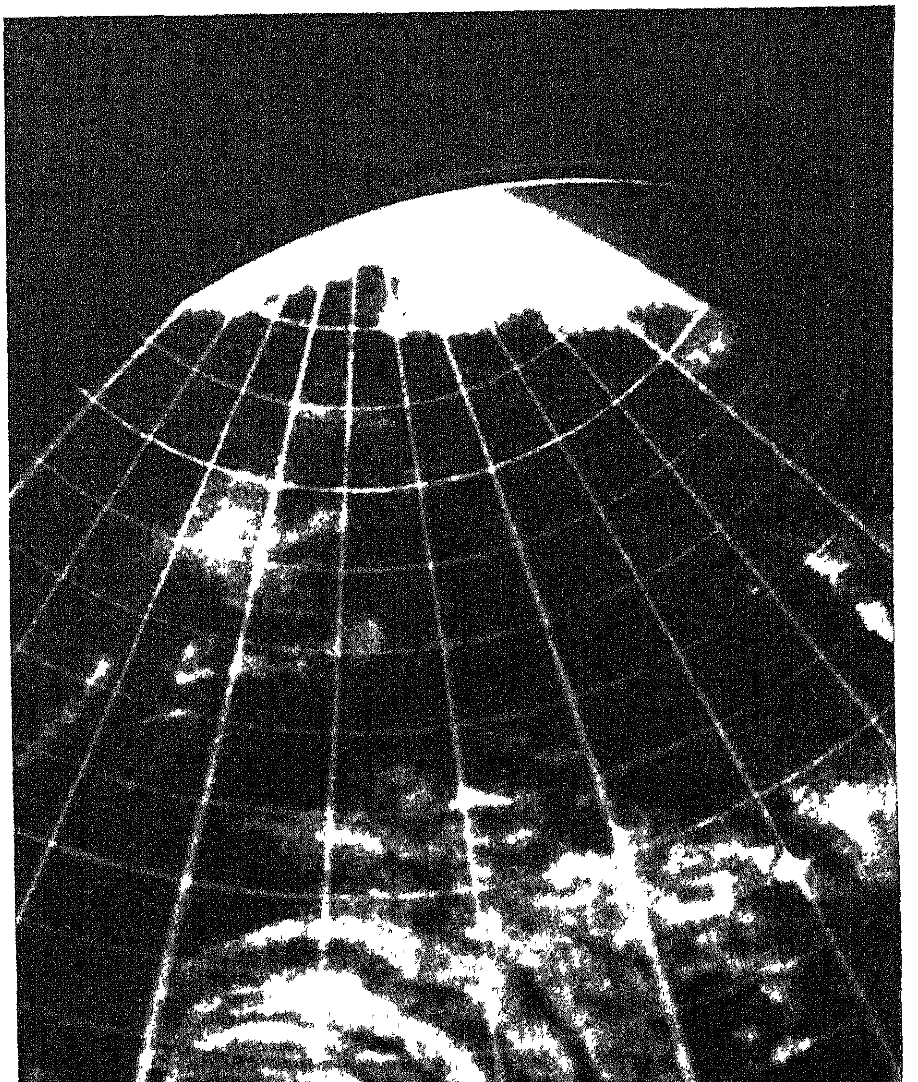
determine the direction in which they were traveling. This method was aimed at the heart of the problem. After determining a few bearings Krug concluded that even with the close spacing of his stations the recorded patterns differed so much at times that they must have been the results of interfering waves from different directions. He calculated that the velocity of the microseisms across his network was 3,600 feet per second, but he pointed out that it could not be determined whether this "unexpectedly low value" referred to the transmission of energy or to the advance of some phase of a combined wave

During the last half of 1938, J. Emilio Ramirez of St. Louis University collected records from a tripartite network. The corners of the triangle were at St. Louis University, at Washington University approximately four miles nearly due west, and at Maryville College about the same distance nearly due south. The first of these instruments recorded the horizontal motion of the waves in the north-south directions, the second recorded horizontal east-west motion, and the third recorded horizontal north-south motion.

During the period of Ramirez's observations, the most important atmospheric storm in the U. S. was the New England hurricane of September 21, 1938. At 7:00 a.m. E.S.T. on September 19, the center of this storm was about 650 miles east-southeast of Miami, Fla. Twenty-four hours later it was 300 miles east of Vero Beach, Fla. On the morning of the 21st it was about 75 miles east of Cape Hatteras, and moving northward at a rate of nearly 60 miles per hour. It passed over the south shore of Long Island at about 2:45 p.m. and swung up the Connecticut River Valley, with maximum winds in the dangerous semicircle reaching nearly 200 miles per hour in Boston. By the following morning, it had become an ordinary low-pressure region north of Ottawa, Canada.

Ramirez reported microseisms coming from the center of this vortex beginning on the morning of the 20th. They radiated from the storm's center as it moved up the coast until it ended on the 22nd. The microseisms reached their greatest amplitude as the storm's eye passed Delaware Bay. The seismograph stations at Harvard and Weston, just outside Boston, were put out of operation by power failures caused by the hurricane, but the seismologist Daniel Linehan at Weston had noted the development of microseisms while the hurricane was still over a thousand miles away.

Ramirez, who published his findings in 1940, reported: "The source of microseisms is to be found not over the land, but rather out over the surface of the ocean. The amplitudes of microseisms depend only on the intensity and widespread character of barometric lows



HURRICANE'S ANATOMY is apparent in Air Force radar photograph corresponding to a plan view. "Eye" of the hurricane is at the left. The whole storm is a low-pressure area. This appears to cause some microseisms.

traveling over the ocean . . . All the determined directions of incoming microseisms at St. Louis point to a deep barometric low over the ocean."

During the war, the U. S Navy established a Hurricane Microseismic Research Project to record and study microseisms in the Caribbean, primarily with tripartite networks and using only horizontal component seismographs. Marion H Gilmore, who was in charge of this program, reported spectacular successes in tracing hurricanes during 1944 and 1945 He also described large microseisms from other sources, such as a cold front passing over the ocean, but did not publish directions of approach for such microseisms.

IN July, 1948, it was announced that the Navy had expanded this program by the creation of a Pacific Microseismic Project, with stations at Guam, Okinawa and Subic Bay, near Manila. Gilmore and his associate, William Hubert, reported that "it is now possible to locate accurately the position of a typhoon by the SEISMO method when it is more than 1,000 miles from the Tripartite Microseismic Station."

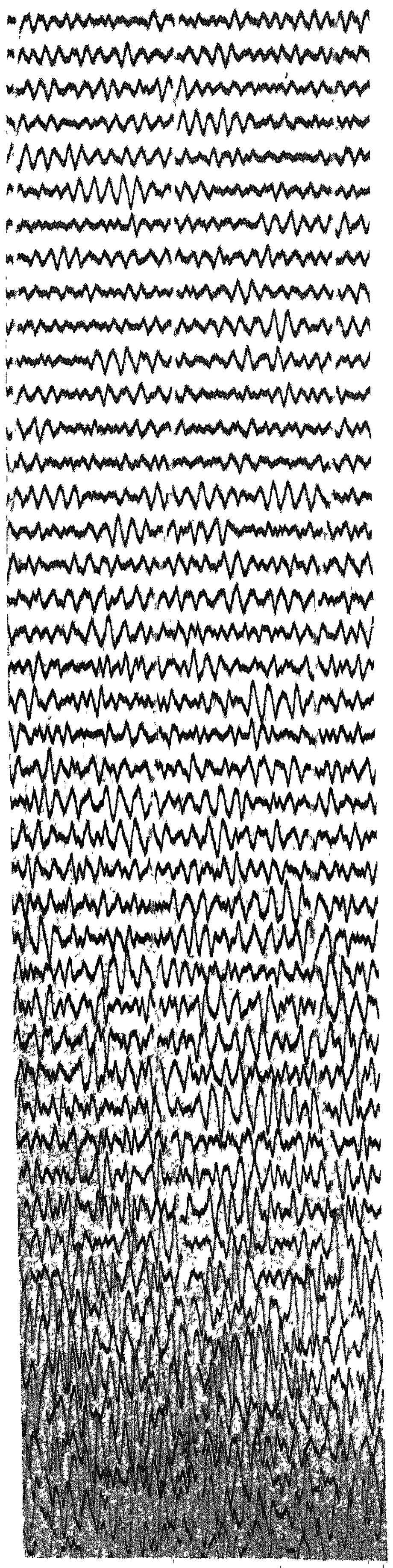
Knowledge of the development, track and intensity of typhoons, of which there have been an average of 20 each year since 1920 in the western Pacific, is of obvious importance to shipping, aircraft and residents of that part of the world. It appears that microseisms are already very effective in this service, and likely to become more so as experience and research advance our knowledge of the subject. The typhoon of June 17, 1947, was the first storm completely tracked with bearings from the Navy's Tripartite Microseismic Station at Guam. Two others were tracked in August, two in September, and four in October of that year. Microseismic storms have also been traced to other air disturbances; in two instances they were attributed to winds of moderate gale force (about 30 knots), in another instance to the low-pressure center of an extratropical storm, and in several cases to cold fronts.

These important successes in the location of hurricanes and typhoons have not only brought microseisms to public attention but have also led to an acceleration of effort on the part of seismologists to gather the types of data necessary to reach a decision as to the mechanism which causes them. In our present state of confusion, speculations on the cause or causes are primarily academic exercises, or at best working hypotheses. One of the few points on which seismologists are in unanimous agreement is that we still do not know the cause.

It is clear by now that the statements to the effect that microseisms radiate only from the center of a low-pressure region were premature and oversimplified. Indeed it has not yet been demonstrated conclusively and without ambiguity that they ever radiate from the actual center of such a low-pressure area Gilmore, who has collected the greatest volume of tripartite data, decided that "the tendency of some writers to 'jump to conclusions' based on too few data is believed to have caused much of the recent confusion and doubt surrounding the true nature and causes of microseisms " He proved the accuracy of his own analysis by concluding in 1946 that "dominant microseismic waves of two- to seven-seconds period originate in some manner near the center of atmospheric disturbances," and in 1948 that "present microseismic data show that microseisms do not always come from the center of hurricanes, typhoons, or extratropical lows "

The tripartite method of determining the direction of travel of microseisms is not infallible. It has been supposed that the direction of propagation of the wave can be calculated by this method regardless of whether it is a true wave of a known type or the product of some very complicated combination of waves. But this view overlooks the laws of combining simple harmonic motions. If two simple harmonic waves of the same period but different phase pass an observing point, they combine to form a simple harmonic wave of pure form which shows no evidence of the combination. And the times of maximum and minimum of the combined wave are different from those of either of the components. If the components are crossing a tripartite network at different angles, their phase differences will shift progressively and they will produce a synthetic "wave" which will be clocked at each of the three stations of the network but will have no physical reality. If two waves of different periods combine, the resultant wave form will show the presence of the components, but again the time at which the resultant reaches its crests will not be the time at which either of the components does.

It is therefore desirable to analyze microseismic waves and attempt to identify a pure wave which may be used as a guide to direction. At least two of the six known types of earth waves have been isolated in microseisms. They are the so-called Rayleigh waves and Love waves. The mechanism by which a Rayleigh wave travels makes it possible to determine the direction in which it is advancing. A particle in the path of this wave moves in an elliptical orbit in a plane oriented in the direction of the wave's advance. It moves forward and upward, then backward and downward. Thus if the motion of the earth in the path of such a wave is recorded in three directions perpendicular to one another, the direction of the wave can be determined. The writer first proposed this method of investigating microseisms in



STORM of microseisms is depicted in segment of seismic record. From top to bottom, record covers 24 hours.

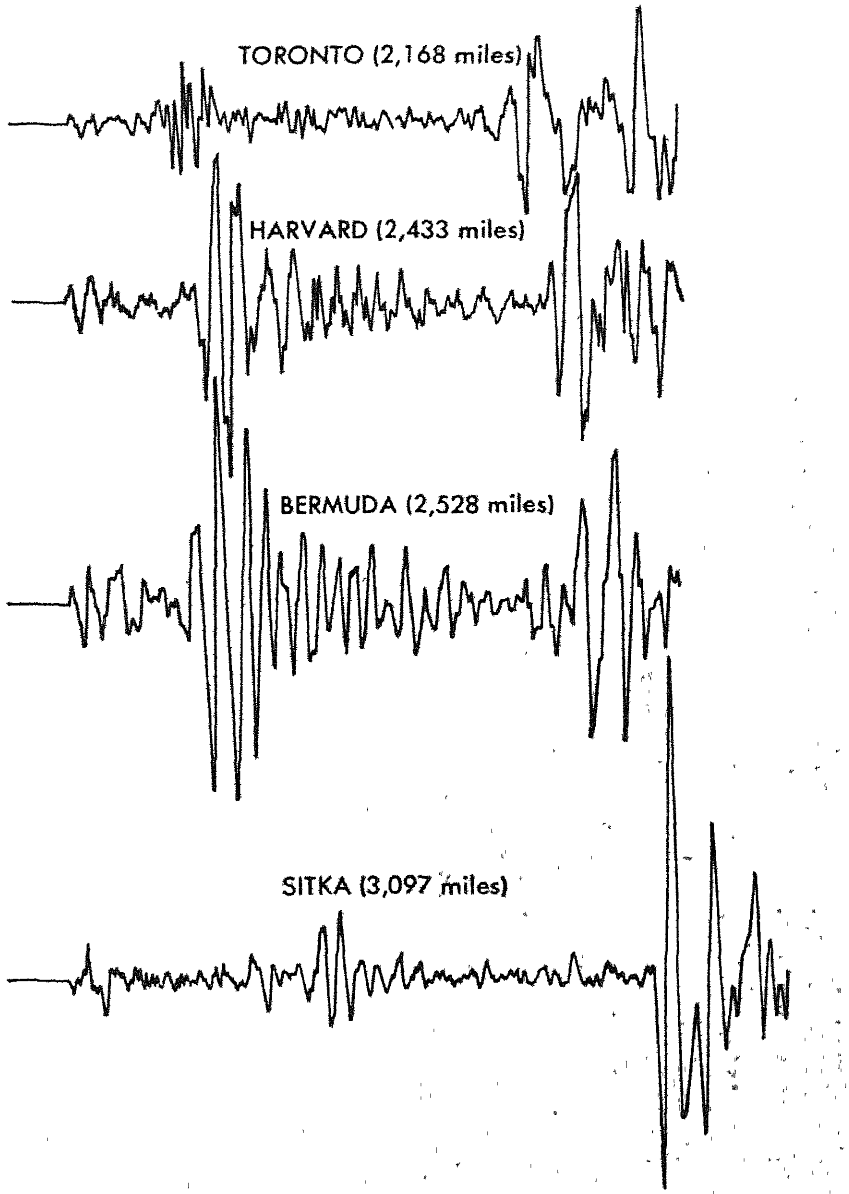
1929, and finally made the experiment in 1945.

On November 14, 1945, a cyclonic storm developed around a low-pressure area at Cape Hatteras. The center of the low moved northeastward to the Gulf of St. Lawrence by the afternoon of the following day, and from there to regions where it was beyond the range of the U. S. Weather Map. In the early hours of the 15th, microseisms began to develop a storm pattern at the Harvard Seismograph Station, with the Rayleigh waves causing motion in the sense: north, up; south, down. Thus they were coming from the south. As the storm advanced, microseisms reached the Harvard station from the southeast, then from the east. At the same time they continued to come from all previously represented directions. They never came from the northeast. After the atmospheric storm had moved off the weather map, microseisms were still coming to the Harvard station from south, southeast and east, as well as from intermediate directions which could not be resolved as clearly. By this time the only part of the storm system that remained in those directions from the seismograph station was a pronounced cold front at which there was a sharply defined change of air pressure. Presumably the microseisms came from the cold front.

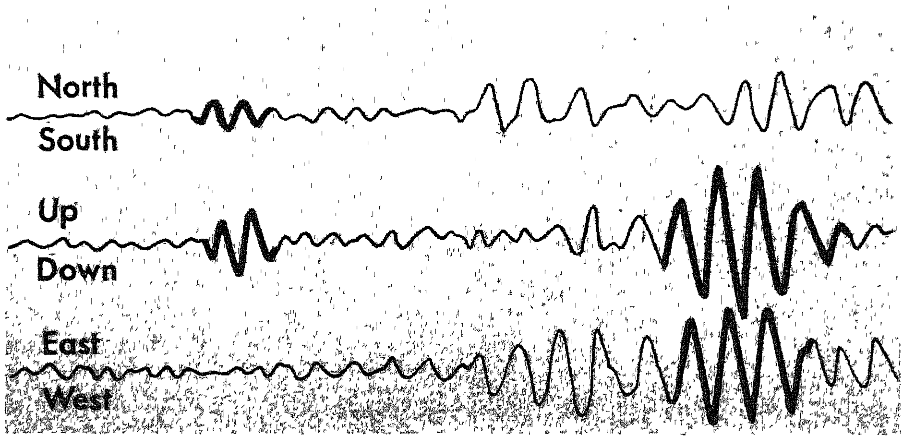
In its present development the Rayleigh wave method does not possess the desired accuracy in determining the direction of microseisms' travel. It is reasonable to expect that an ultimate solution will be found in a combination of the Rayleigh and the tripartite methods. With three components recording at each corner of a tripartite network, it may be that the character of the record and wave types can be analyzed in such a way as to spot the occasional isolated microseism that passes without interference from other directions. When this has been done, the direction of its travel can be fixed precisely by the relative times of its passage at the three corners of the network.

The backlog of unsolved problems has not prevented development of practical applications of microseisms. They carry their messages thousands of miles at rates of from one and a half to two miles per second, night and day, in fair weather and foul. Some of the messages are already being interpreted as warnings of hurricanes and typhoons. Others will serve new uses when we crack the code. But there is a lot of midnight oil yet to be burned before we can write the full story.

L. Don Leet is professor of geology at Harvard University.



MEXICAN EARTHQUAKE of April 15, 1941, produced similar wave patterns at four different stations. The patterns of microseisms, in contrast, differ from one location to another. Microseisms also come from many directions.

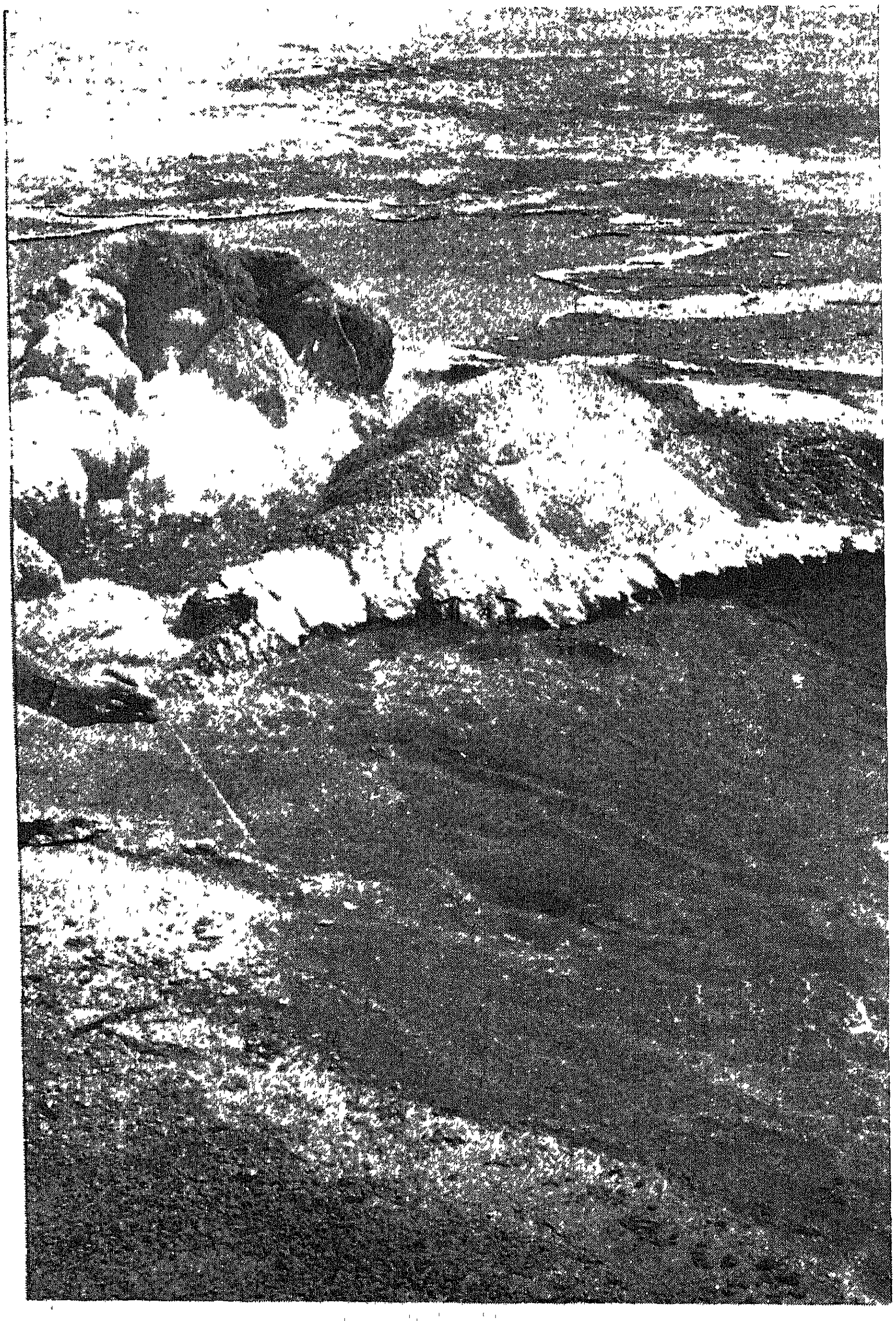


RECORD OF MICROSEISMS made at Harvard University station shows variable relationship among three traces. Two heavy curves at left were written when low-pressure area was near station. Pattern shifted quickly.

Temperature and Life

The thermal environment of organisms is a tiny segment of the thermometer. Some forms, however, have penetrated forbidding regions of heat and cold

by Lorus J. and Margery J. Milne



HOT SPRING in the Upper Geyser Basin of Yellowstone National Park has a temperature of 190 degrees F. At left its temperature is measured. Spring contains living bacteria, and the travertine rock about it is colored by algae.

ONE of the facts learned early by every child is that hot things hurt the skin. At the other extreme, "dry ice" (solid carbon dioxide) can cause burnlike damage to fingers that hold it firmly for only a few seconds. The range of tolerance of human skin is narrow. A human hand, normally maintained at slightly below 98 degrees Fahrenheit by the circulation of the blood, which is heated among the muscles and thermostated in the brain, cannot stand immersion in water at a temperature of 140 degrees F. for more than a few seconds. Drinking hot liquids offers a close parallel. Many throats rebel with hiccup spasms if subjected to beverages above 136 degrees.

Indeed, life itself is huddled into a short segment of the thermometer, not far above the absolute zero of temperature. Most animals and plants are killed by continued contact with water at 106 degrees. Man's life ebbs away quickly if his blood heat reaches this fatal point. There are many "lesser" creatures, however, that thrive under such adverse conditions. They are widespread in the boiling springs and geyser basins of Yellowstone National Park, and in other thermal waters scattered over this continent. These hot liquids hold tremendous interest, not only because of their volcanic relationships and spectacular performance, their variety of chemical compositions and temperatures, but also because they have been invaded successfully by a curious assortment of animals and plants.

Their temperatures, to be sure, are limited to the relatively low maximum attainable by water, which normally cannot exceed 212 degrees F., and boils far below that temperature at the high altitudes where many of the hot pools are found. Nevertheless there is still room for man to marvel at animals and plants that can tolerate temperatures so far above the normal range.

Recently we visited western Wyoming to make a survey of life in the thermal waters of Yellowstone Park. Armed with a thermometer, a permit from the superintendent, a pair of long forceps and other collecting gear, we stepped gingerly to the edge of pool after pool, and followed the small streams, hotter than bath water, which run off from the springs and geysers and cool in the open air. While many of the steaming pools gave no obvious sign of being inhabited, the pastel colors of the bottom mud told us that microscopic plants must be living there in great numbers. Too torrid for animal life, these hot springs often were spotted with floating dead insects that had been interrupted in their flight by the rising steam and had fallen in to drown. The hot water quickly stopped their struggling. Occasionally a tourist's dog meets the same fate when the owner ignores the Park Service rule and slips

its leash. The excited canine jumps to an almost instantaneous death—violently emphasizing the point that the presence of a few special kinds of plants is no indication that other forms of life can survive the heat.

Some green plants grow in hot springs at 145 degrees F., and forms devoid of true chlorophyll exist at 162 degrees. Some in alkaline, silica-charged waters have been reported tolerating 194 degrees indefinitely. At the altitude of Yellowstone Park, this is approximately the boiling temperature of water

At 150 degrees and just below, most pools contained a pale gray-green bottom cover of algae. Gas bubbles collected below this mat of material. In many places the algae had grown upward in long fingers, suggesting the "mineral gardens" that some people prepare as table decorations. We could not be sure whether the gas was of volcanic origin or was oxygen liberated by the green cells in the sunlight as a by-product of their photosynthesis. Research reports suggest that much of the gas is oxygen

IN water at 120 degrees we found bright red "bloodworms" in the gray mud below the algal mat. These are the young of certain midges that resemble mosquitoes or miniature crane flies. They are red because they have true hemoglobin in their blood. The bloodworms are among the few insect larvae known which can thrive where oxygen is practically absent. Through tricks of chemistry they manage to bridge long periods of adverse conditions that would suffocate almost any other animal. Here they were in the hot water, occupying another niche where few forms can live. The adult insects lack the red color. They land on the water surface, and no doubt drop their eggs from this precarious position.

We found other bloodworms that had lost both their hemoglobin and their lives. They were stiff and brittle—coagulated like the white of an egg. We probed the bottom where they lay, using our thermometer to disturb the algal mat. In that spot the stream was fully 10 degrees hotter than elsewhere, due to the inflow of liquid from another hot spring; the rise of temperature must have caused their death.

Where the runoff streams had cooled to 115 degrees F., and in pools with this surface temperature, we located more live bloodworms and an occasional gray, leathery, telescoping larva that we recognized as a juvenile soldier fly. At slightly lower temperatures were a few large brown mites—relatives of ticks and spiders—about an eighth of an inch in length. For mites, they were huge.

When we came to waters around 110 degrees, the water surface and adjacent soil were spotted with active little flies. Their young scavenged the hot streams and shallow edges of the pools. We tried to catch some of the alert adults by sweeping a net over their resting place. Ordinarily insects take fright and fly up into the approaching cotton bag. But these flies clung to their places or waited until the net was past, and then flew away We watched them for a while and discovered an enemy catching far more of them than we could. A tiger beetle, with an inconspicuous brownish back and a bright red abdominal undersurface, rushed at the little flies with scimitar jaws spread wide and often caught them before they jumped away. The beetles flew before our footsteps Apparently their chief food along the hot-spring runoff streams is this little fly—a "brine fly" of the genus *Ephydra.*

The brine fly is one of the most adaptable of animals. We had met it before in tidal pools among the rocks of the Maine coast, and it has been reported as thriving in the vats at saltworks where the water is saturated with sodium chloride. A relative of the brine fly lives in petroleum pools, and feeds on other insects that fall into the poisonous oil and die there.

Slightly cooler water, though still above human blood temperatures, contained many more kinds of living things. mosquito wrigglers, diving beetles, caddis worms, water snails of the left-handed genus *Physa.* Shrimplike *Gammarus* were there, scudding along the bottom with pale flat bodies that reminded us of relatives of theirs found in cool ponds in New Mexican lava beds, in New England streams, and along the shallow shores of the Great Lakes. "Water boatmen" of small size swam jerkily or rested on the green bottom of the spring in such numbers that they suggested an aerial view of New York's Central Park on a Sunday afternoon with crowds sitting on the grass.

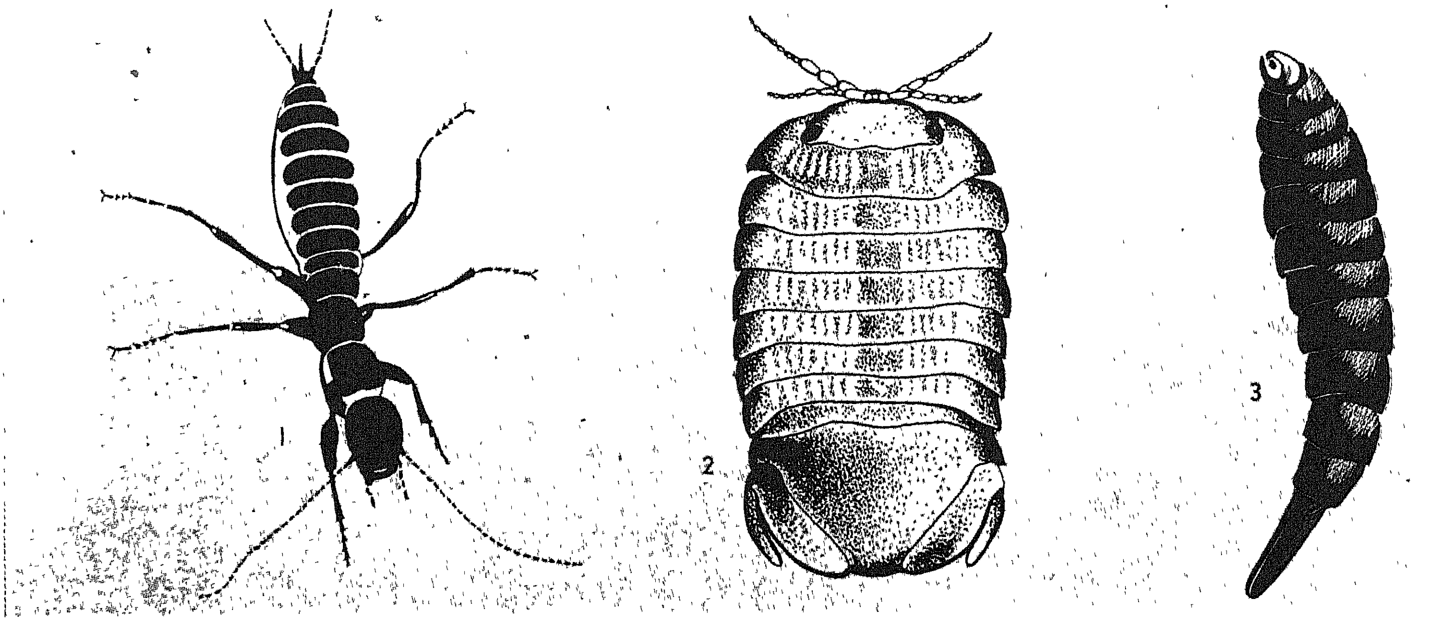
AS we looked into water of lower and lower temperatures, all of the normal aquatic animals appeared. Fish were among the last, and the only place we found them in association with hot springs was in a cool pond that had a source of thermal water at one side. The fish were along the opposite shore. Apparently they cannot stand the higher temperatures.

Almost all of the plants in thermal waters are bacteria or seaweedlike algae. Some of the former gain their living through a very complex chemistry, involving sulphur or iron compounds such as stain some hot springs and create bright crusts around the margins. These and a few of the algae precipitate the lime from hot water and make of it a kind of porous rock called travertine; they often build great terraces in this way. Others have a similar effect on silica-charged waters and produce a glassy sinter. These chemical reactions are substitutes for, or predecessors of, the process of photosynthesis by which most plants live. Most of the blue-green algae in hot waters and green algae in slightly cooler ones seem to require sunlight, as do green plants at normal temperatures. With very few exceptions, the living things, both plant and animal, that survive in hot water differ little from those found at ordinary heat levels. They exist there not because of the high temperature but in spite of it. And most of them belong to groups of creatures that elsewhere show much adaptability to strange modes of life.

MANY terrestrial animals and plants that never go near a hot spring live in climates that occasionally produce temperatures high enough to cause burns In order to survive, these non-aquatic forms must be able to find refuge from the heat by burrowing in the ground, or must cool themselves by evaporation. Most plants and many animals employ the latter technique. Every unit of water evaporated from the living tissue removes enough heat to cool a hundred units of water in the tissue by 10 degrees F. But where water is scarce, this method of refrigeration is not safe; the organism must find some other means of self-preservation.

Plants may drop their leaves, even die down to the ground, and conserve life in their roots in the cooler depths where the summer sun cannot reach. This in a sense is burrowing too. Or, like the cacti, they may abandon ordinary leaves, from which water evaporates, and store water in fleshy stems covered with a waterproof skin—their leaves are converted into spines which keep thirsty animals away. The excess temperature gained by the cacti during a sunny day is radiated off again at night to keep the plant within its range of tolerance. In some plants watery solutions, circulating between sunlit and shaded regions of the plant, distribute the calories so that no part becomes too hot. When this process fails in a dying tree, insect invaders beneath the bark may be cooked by sunlight they never see. In such a case the temperature under the sun-baked bark may reach levels comparable to that of desert sands, even when the trunk stands in an open glade of a northern forest. The insulating layer holds in the heat gained from the sun, and up goes the temperature.

Animals that live in deserts run a constant risk of death by heat. On this perilous borderland lives the horned toad, a ubiquitous inhabitant of the great arid areas of western North America. It survives in deserts where the summer sun bakes the surface sand to terrific temperatures and the air itself reaches well over 100 degrees even in the shade. Horned toads like heat. They operate



A FEW STRANGE CREATURES that exist at extremes of temperature are shown in these six drawings. *Grylloblatta* (1) is an insect that lives in cold soil near glaciers. The isopod crustacean *Exosphaeroma thermophilum* (2) lives in hot springs. The larva of the soldier fly (3) is found in relatively cool warm springs. The amphipod

most efficiently around 102 degrees; and at 80 degrees, when man begins to mop his sweaty brow, these lizards are too cool to function properly. But their optimum temperature is very close to their limit of tolerance. A temperature of 106 or 107 degrees is fatal to them. In the heat of the day they escape by burrowing underground. When the sun drops lower in the afternoon sky and the sands radiate some of their excessive heat, out pop the horned toads again. They scamper about catching insects. The toad even prolongs its active day by deliberately tilting its body so that the flattened back will be at right angles to the sinking sun and collect as much of the radiant heat as possible. When night falls, reptiles such as the horned toad become much less active.

Birds and mammals are a good deal more adaptable. They possess a thermostatic control in the brain which responds to any cooling of the blood by making various internal muscles contract a little. The contraction uses stored food and oxygen and liberates the energy as heat. The heat makes good the losses from the animal's blood to its surroundings, so that its temperature stays at an even level. Birds may also fluff out their feathers, and mammals may elevate their fur a little, to trap air next to the skin for insulation.

Warm-blooded animals also have ingenious mechanisms for adjusting themselves to the heat when the surrounding air approaches or even passes the temperature of their blood. Birds are equipped with long tubes which extend from their lungs into the viscera and even into the long bones of the legs and wings, the chief sites of heat production. When a bird inhales, the tubes are filled with air, when it exhales, the tubes collapse. The expelled gas carries away the heat the bird must dispose of to keep its body at its normal temperature of 101 degrees With the gas goes some water vapor—evidence of evaporation which has helped in the cooling.

Mammals depend more on evaporative cooling, and many have developed abundant sweat glands in the skin from which to ooze water taken from the bloodstream. They may put out a dripping tongue and pant as a dog does, or perspire in other areas according to their kind. A cat has sweat glands only on its feet. A horse has them well developed over most of its body. A camel withstands the desert temperatures by radiating through an unusually thin skin. Its store of fat is concentrated in its hump (two humps in the dromedary) instead of being distributed over its body as insulation.

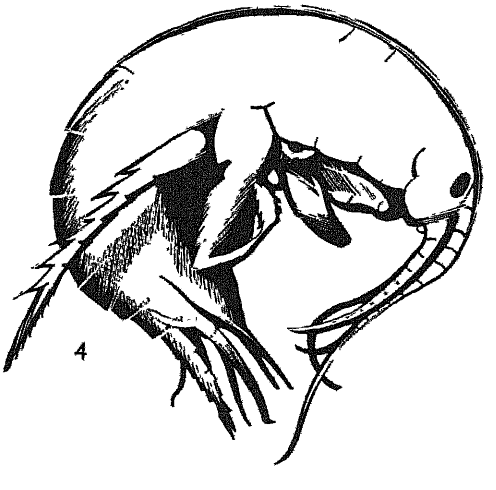
That the ability to perspire is not developed sufficiently in many mammals to ensure their survival is shown by exposing test animals to high temperatures, such as the 120 degrees to which the air in Death Valley rises daily in summer. Man can survive such heat, but a rat dies in 32 minutes. Guinea pigs last an hour.

MOST of the investigation of these problems was the result of certain experiences of troops during the recent war. Maneuvering in tropical marshlands, men began to fall out from what seemed to be heat shock, although the air temperatures were not excessive. It was discovered that their prostration was due to wading in the shallow hot water of the swamps. Laboratory tests were then undertaken to seek a possible remedy.

It was found that if the body of a rat is kept at a comfortable temperature of 68 to 70 degrees and its feet are immersed up to the knee joint in water at 113 degrees, the animal dies in less than three hours. Guinea pigs are not killed unless immersed to the joints between legs and body—the equivalent of a man's hips. The symptoms are those of heat shock, but they are not produced by a general rise in body temperature. Nor is such water burning hot, at least by human standards, for the temperature of an ordinary "hot" tub bath is 107 degrees and people often bathe in even hotter water without fatal results.

Apparently living tissue, when damaged by mangling, by lack of oxygen, or by higher than normal temperatures, produces a toxic material that can sicken or kill the whole animal. The toxic substance—unidentified as yet—produces the shock symptoms. While research in this field is still inconclusive, the chief source of the poisonous substance is suspected to be muscle tissue. No means has been found yet to avoid the consequences of such high temperatures. The effects here described are known to be quite different from the familiar loss of blood salt through excessive perspiration, which can be remedied simply by taking salt tablets in copious amounts of water to cancel the deficit.

Molds and bacteria are a great deal more resistant to heat than higher forms. Often they cannot be killed even by



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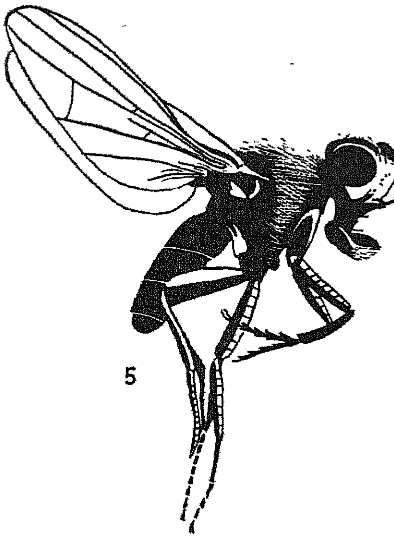

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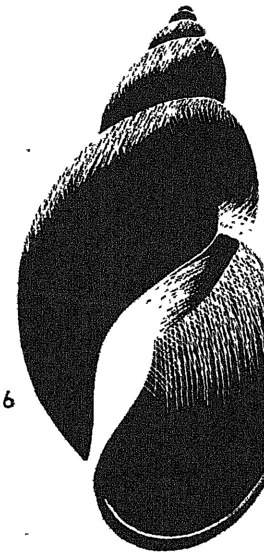

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crustacean *Gammarus limnaeus* (4) dwells in a wide variety of thermal environments, from warm springs to cold arctic ponds. The brine fly *Ephydra* (5) can live in pools which are both warm and extremely salty. The pond snail *Lymnaea palustris* (6) has been found in warm springs that possess a high content of sulphur.

boiling water except under pressure. In a pressure cooker or sterilizing autoclave, when the pressure is raised to double that of the normal atmosphere (*i.e.*, 30 pounds instead of 15 pounds per square inch) and steam is allowed to drive all air from the container, the temperature rises to 250 degrees. Under these conditions bacteria and other harmful organisms succumb in less than 15 minutes. It is not the 250 degrees temperature alone that kills them, bacteria can survive almost an hour at 320 degrees if the air around them is dry. But in live steam at 250 degrees they are destroyed because they cannot release their water.

Most mammals must hold their body temperatures within very narrow limits to remain healthy. In a human being a fever of 102 degrees involves a speeding up of chemical activities in the body by almost 25 per cent, and a drop to a "subnormal" 96 degrees means a 20 per cent decrease in the rates of vital processes. Yet a bear or a bat in hibernation lives at a temperature only a few degrees above the level of its cave or den, perhaps 40 degrees F.! Living on stored fats and oils, these torpid animals can slow their metabolism to 10 per cent of the normal rate. Most cold-blooded creatures react in the same way, they can even relapse into a hibernating sleep for a single chilly night.

At hibernating temperatures, neither mammals nor reptiles are capable of activity. Still, just as there are a few animals that can live normally in hot springs, so there is also a scattering of creatures that manage to live active lives at the temperature of melting ice, 32 degrees F. The snow flea, a tiny black pest of the maple-sugar country, lives largely on the snow. By night the insects freeze, by day they frisk about. The special mechanism that enables them to be active at such temperatures is not yet understood. On the banks of streams and rivers in early spring is found another small, hardy insect, the wingless black stone fly, which mates, lays eggs and dies on the ice. Members of other groups are active too; one of them is the rare wingless scorpion fly, *Boreus*, named appropriately after Boreas, the Greek god of the north wind.

At this season each year some people are surprised to see large areas of snow fields turn suddenly pink or even red. They acquire their color from myriads of microscopic plants that can be active and multiply in spite of the low temperature. "Red snow" is due to a bright masking pigment that these simple algae contain in addition to green chlorophyll.

On snow fields and glaciers down the crest of America from Alaska to Mount Rainier in the state of Washington live diminutive, soft-bodied relatives of the earthworm—the "glacier worms." In a 2,000-year-old lava field in the New Mexican desert west of Albuquerque there are algae that live at the freezing point of water. Some parts of the field have shallow caves, five to 30 feet deep, in which water collects from the melting of winter snow. A few of these caves retain winter's cold throughout the summer, their floors are smooth, clear ice. In one cave, which has a rough window in the lava roof through which the noonday sun sends a narrow shaft of light, the sun's rays daily melt a basinlike pool in the ice. The water is pale green, with thousands of single-celled plants that make use of the sunlight and the cold water. They form green rings in the ice that show how the path of the sunlit patch changes as the earth swings in its orbit around the sun.

Most famous of all dwellers in this realm of low temperatures are a universally known plant and an insect well known to scientists. The plant is edelweiss—an Alpine flower withstanding the nightly frosts at high altitudes. The insect is *Grylloblatta,* found among the glacial debris near Lake Louise in the Canadian Rockies. *Grylloblatta* looks like a cross between a cricket and a cockroach. In its architecture are features that have remained unchanged since the dim geological time when insect kinds were fewer and far different. Early in its ancestry, this strange creature became adapted to living under stones where the temperatures stay close to the freezing point. It remained on ice, both literally and figuratively—a living fossil from which has been learned a multitude of details that help us to understand the biology of early insects. *Grylloblatta* has carried its ability to withstand low temperatures to an extreme met in few animals. It can no longer tolerate heat in the normal range of insect activity. Placed on a human palm, it "burns" to death within a few minutes.

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Three Mysteries of Easter Island

In which the symbols of the enigmatic Polynesian culture are investigated by the methods of the modern psychologist

by Werner Wolff

ON the morning of Easter Sunday in 1722, the Dutch explorer Jacob Roggeveen landed on an uncharted, thickly populated island in the Pacific 2,000 miles due west of the Chilean coast and 1,100 miles southeast of Pitcairn, the nearest inhabited island. Roggeveen called his discovery Easter Island. He found a lava-covered strip of land 13 miles long and seven miles across at its widest point, practically destitute of vegetation, hemmed in by extinct volcanoes and precipitous cliffs 1,000 feet high, and covered with a weird profusion of ancient human relics which ever since have remained one of the principal puzzles of anthropology.

The most spectacular of Easter Island's mysteries is the multitude of gigantic stone statues, 30 feet tall and weighing 50 tons or more, which lie scattered over the island like seeds tossed at random from some giant's hand. The meaning of these statues with long ears and shapeless bodies is itself an enigma. Even more baffling is the question of how the massive objects were moved from the volcano crater, where they appear to have been manufactured, to the various sites, some of them atop high cliffs, where they were found.

Decade after decade even more intriguing material has been uncovered on Easter Island—by W. J. Thomson leading an American expedition in 1886, by Mrs. Scoresby Routledge of a British expedition in 1914-16, and by A. Metraux and H. Lavachery of a French expedition in 1934. They found wooden tablets with hieroglyphics that have never been satisfactorily deciphered, carvings in rock of creatures half bird and half man, wooden idols 20 to 30 inches high.

The three basic questions posed by these strange relics are: What was the origin of the Easter Islanders and their culture? What is the meaning of their hieroglyphics and symbols? What is the answer to the enigma of the statues?

To these questions I have attempted to apply a new approach—a psychological culture-analysis suggested by the methods used in the psychological investigation of individuals. The essence of this approach is a search for the natives' associations with each symbol, and an attempt to find in these associations common denominators that may reveal the Easter Islanders' view of life and the world. For instance, the form and size of the Easter Island statues cannot be considered accidental. The statues must be interpreted as symbols in a larger context; they are like images in a dream which must be analyzed in relation to other associations.

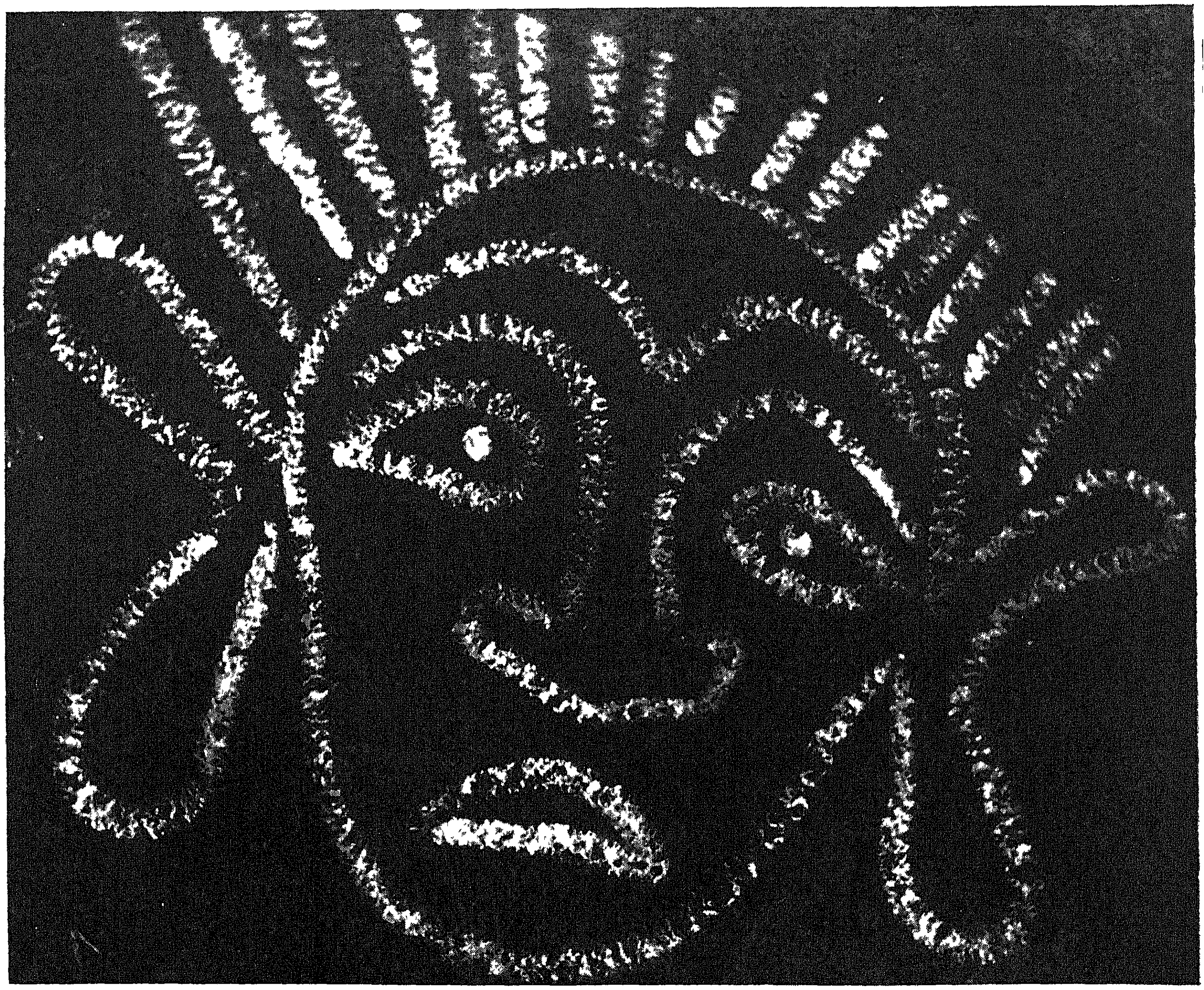
In attacking the problem of deciphering the Easter Islanders' symbols we are assisted by a net of relationships among the natives' chants, ceremonies and inscriptions, and the similarity of their language to others. We have much comparative data from other Polynesian islands, with which Easter Island apparently had a cultural connection, and, as we shall see, there are similarities to more distant cultures.

The wooden script tablets on Easter Island are called *kohau rongo-rongo*, generally translated as "singing wood." They were supposedly brought to the island by a king named Hoatumatua, probably around 800 A.D. The natives tell of an ancient yearly ceremony performed by singers called *rongo-rongo* men. Wearing feather headdresses, they sat in rows facing the king and chanted the text of the tablets.

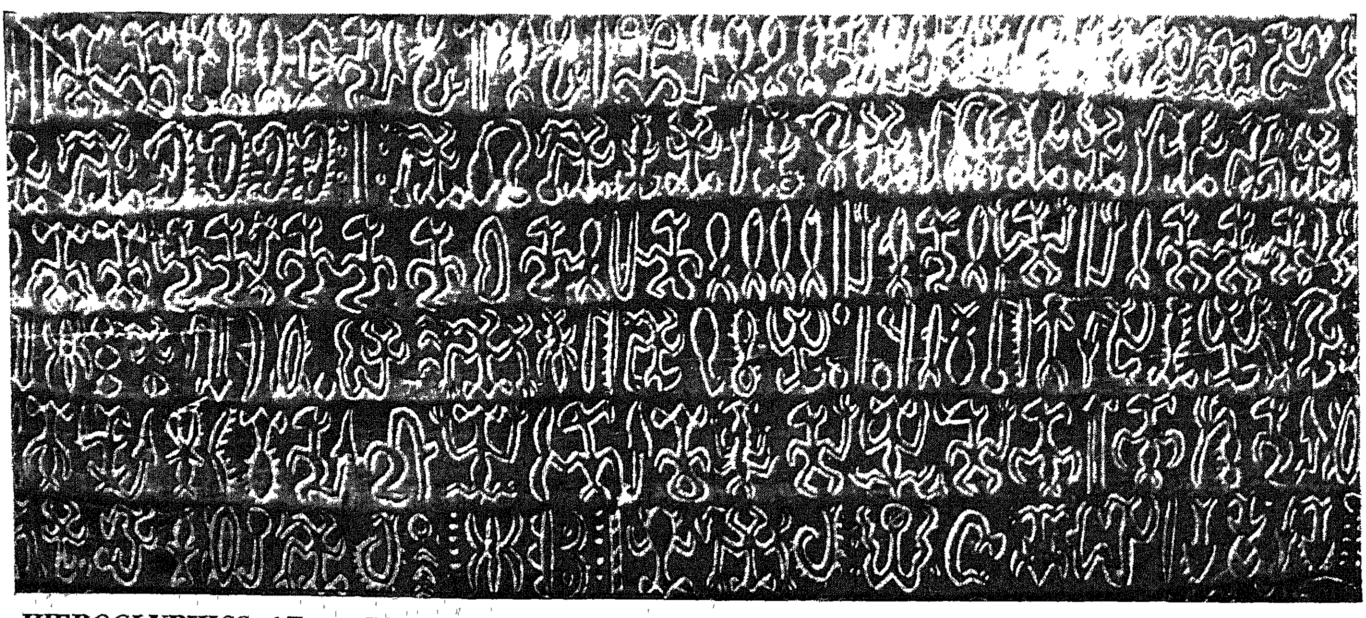
In this ceremony we find a common denominator in the feather headdresses of the singers and the added fact that each singer received from the king a

FAMOUS MYSTERY of Easter Island is the great stone heads scattered on the slope of the volcano

Rano Raraku. Many of the heads are unfinished; some lie in the places where they were quarried. How they were transported to their various locations is not clear, although the author offers a theory. An island legend relates that a group known as the Short-Ears made the heads to commemorate a group they had massacred.



ROCK CARVINGS of Easter Island were one source of the symbols interpreted by psychologist Wolff. When the meaning of the island's hieroglyphics (*below*) had been deciphered, they could be compared with other symbols. This process illuminated some of the motives that impelled curious cultural behavior of the islanders.



HIEROGLYPHICS of Easter Island have some similarities to the Egyptian. First attempt to translate a tablet bearing them failed because a native interpreter deliberately distorted its meaning. The interpreter, however, composed a dictionary that was perfectly clear. This was successfully used by the author to decipher the tablets.

chicken. The symbol of a bird is further expressed in an annual spring egg hunt around one of Easter Island's volcanoes, in which the singers took part. The finder of the new egg received the preceding year's egg, which had been buried inside a gourd in a cranny of the volcano The hunter, called a bird-child, had hieroglyphics painted on his back similar to those on the backs of the statues and on the wooden tablets. A native interpreter has explained this glyph as a sign for the sun. The hunter also was required to shave his head and paint it red—another symbol for the renewal of the spring sun. All these indications have led us to interpret the ceremony and the chants as a ritual of rebirth.

This interpretation is supported by the fact that the reading ceremony was held near the *ahu* or burial place. The name of the tablets, *kohau rongo-rongo*, itself suggests a relationship to death, for *kohau*, wood, also means the shaft of a lance, and a similar word, *kohu*, means shadow or obscurity. Thus the tablets seem to be related to rebirth in the same sense as was the Egyptian Book of the Dead.

THE first attempt to decipher the Easter Island tablets was made by Tepano Jaussen, Archbishop of Tahiti, who began the task in 1868. He was assisted by a native interpreter named Metoro Tourara. Metoro informed him that the reading of a tablet started at the bottom from the left, followed the next line from right to left, and proceeded in that serpentine fashion up the tablet. This system, known in several ancient civilizations, is called *boustrophedon* (meaning as one leads the oxen when plowing). It permits the reader to follow the lines without interruption. Metoro interpreted the hieroglyphics on one wooden tablet to provide a dictionary. He also translated the tablet, but the translation completely puzzled Jaussen. In publishing it he observed. "One has to resign, there is no sense in it"

I discovered this translation in Paris in my search for documents on Easter Island, and decided to re-examine it from a psychological point of view. It is well known that many primitive peoples are secretive about their tribal traditions and resist efforts of strangers to decipher their writings I considered the possibility that Metoro may have cleverly misled Jaussen. To test this assumption I compared the dictionary of glyphs with Metoro's translation and a photograph of the tablet.

It appeared that Metoro had given the correct meaning of the glyphs in many cases, at least where the meaning could be deduced by a stranger from the form of the symbol. His statement that the tablets were read by the *boustrophedon* method also seemed to be correct, for the glyphs in successive rows appeared as figure reflections would appear in water, head meeting head. The meanings given by Metoro for the glyphs in the first three rows appeared to be accurate —as far as they went. Yet the chant he translated from the entire tablet certainly did not make sense. Furthermore, it was shorter than it should have been according to the number of glyphs.

A close comparison of the dictionary definitions with the glyphs in the first three rows of the tablet and with Metoro's translation of the chant revealed that he had omitted some of the glyphs, varied the meaning of others, inserted "translations" of others which were not present, and, to crown the deception, had translated only one row of the tablet

In his dictionary, however, Metoro appears to have given the true meaning of the glyphs. When I used these meanings to translate the first three rows, I obtained three coherent, intelligible chants, which are consistent with concepts in the spoken language of the Easter Islanders. The translation of the first line is:

He lives in heaven, on earth, land of Hoatumatua, [he] lives, he lives in heaven, on earth. [On] earth, the eldest prince lives [on] a boat The younger brother, the child, he is gone to heaven, on earth, the land of Hoatumatua, the brilliant. He is gone to heaven, on earth [On] earth the eldest prince, the brilliant, the father is sitting on his throne. The child is joyous in heaven. The bird flies [over] the earth. Man eats, lives, man is at work, man is at work. The fowl flies [over] the billows, the fowl flies [over] the tilled soil, the fowl flies, lives. The king, man lives, the children. The child [on] earth he has left.

At first glance the chant appears strange. Compared with the old Egyptian chants, however, it is a model of clarity. If it were translated idiomatically instead of literally, glyph by glyph, its meaning would emerge more clearly. Certain details of the chant are corroborated by legends of the island. One tale relates that Hoatumatua, the first deified ancestor-king, was looked on as the mediator between heaven and earth. The allusion to the boat on which he, the eldest prince, is living seems to refer to Hoatumatua's arrival on the island by boat.

THE next question that arises is: What common elements can be found in the tablets and the statues?

Clues to the meaning of the statues may be sought in the folklore and customs of the islanders. Most of the statues, which were carved from lava stone, were found in and around the crater of the largest volcano on the island. Their position, and the distinctive long ears that characterize the figures, may be explained by an island legend The legend says that from the first immigrants to the island there descended two tribes: the "Short-Ears," descended from Hoatumatua, and the "Long-Ears," from Machaa, his younger brother. After a time the Long-Ears became clannish and settled on the top of the volcano, where the workshop for carving the statues was located. They ruled the Short-Ears for a while, but after one of their number killed and ate 30 boys of the Short-Ears, the Short-Ears slew all the Long-Ears and took over the workshop of their former masters.

Thus the statues may commemorate the long-eared ancestors. But why were these ancestors idolized as statues after they had been murdered as enemies? According to all observers, the natives on Easter Island believed themselves to be constantly under the influence of the spirits of departed souls. The fear of death was always present. The statues' position at the burial place connects the ancestors with the concept of death. The natives' fear that the murdered clan might take revenge on them might have induced them to construct the statues for appeasement.

Some of the statues have carvings of birds on their backs. The natives' name for statues, *moai*, which has never been explained satisfactorily, seems to connect the symbol of the bird with that of the ancestor. *Moa* means bird, and the *i* in *moai* is the common Polynesian root for ancestry In Polynesia and Central America the souls of the departed often were represented as birds. Bird designs cover the walls of the "Eat-Men-Cave" on Easter Island where cannibalistic feasts were held.

The bird ceremony on Easter Island seems to explain why the bird was selected as a symbol of the departed soul. This ceremony celebrated the arrival of spring. The bird was not only a symbol of the soul but also of the sun, which is depicted as a firebird in ancient religions of the Old and New Worlds. The bird ceremony appears to have been a prayer for revival of the sun and of man's spirit after death

The idea that life feeds upon death was expressed in Polynesia by the sea bird, symbol of life, which lives on the fish, symbol of the victims of human sacrifices and of death. Life was supposed to be an energy, *mana*, which could be ingested by eating human flesh. The life energy could also be stored in stones, which were particularly good receptacles because of their durability. The Easter Islanders had so-called *mana* stones which were carried as charms in hazardous enterprises. The statues, then, appear to have been repositories of *mana* that was extracted from the victims and offered to the ancestors as a gift of eternal life in appeasement for their murder. In some way the statue was also the

token of the flying bird, whose flight was a *symbol of the ever-moving* energy of life.

These concepts can be discovered all through Polynesia and Central America. Mexican manuscripts, for example, show that the *sun* was fed by the life force contained in human hearts, which were offered to the gods on stone pyramids.

Yet the transportation of the statues remains a great riddle. Thomson was "unable to arrive at any satisfactory conclusion as to how the immense statues on the upper tier of the works could be moved to the plain below." Mrs. Routledge found a statue on a natural eminence, one side of which was a sheer cliff and the other a slope as steep as a house roof. Some students of the problem have suggested that the Easter Islanders may have hauled the statues by means of rollers and ropes over old roads that may long since have been obliterated. But some of the figures are on heights to which no roads could have led, and the island has always been lacking in wood or any material from which either rollers or ropes might have been made. Moreover, it is impossible to explain why the statues, made of friable lava stone, did not crumble or break when they were moved. There are other aspects that have bewildered investigators. The statues are strewn about in no particular order. Some lie on their faces and some on their backs. Many are unfinished. One hundred fifty-seven statues are still in the quarries where they were cut, lying "in the least accessible places," as Metraux observed.

Most striking of all is the fact that the work on the statues appears to have stopped abruptly. The sculptors left the images in all stages of construction. They must have left hurriedly, leaving behind some of their tools—stone chisels that resemble paleolithic hand axes found in Europe. It seems likely that their work was interrupted by a sudden eruption of the volcano.

All this suggests that the transportation of the statues was related somehow to volcanic activity. The sculptors may have found a way to use the volcanic forces to move them. This theory is strengthened by the fact that all the statues are partly buried in volcanic ash. Some natives reported, according to Mrs. Routledge, "that the statues were set up to be finished." Thus it seems that the statues may have been carved in the rough in the crater, transported by the volcano's eruption and finished in the places where they fell. Many statues, however, lie there in a broken state. If the hypothesis of volcanic transportation is accepted, it at once becomes possible to account for many of the other mysteries—the location of the workshop in the crater, the scattering of the great 50-ton masses of stone, the strange positions and helter-skelter disorder in which they were found.

Our theory gets some support from the language, folklore and symbolic system of the natives. The statues were given names that refer to flying birds. One statue has the name *Viri-viri-moai-a-taka*. *Viri-viri* means to roll, *moa* means fowl, *taka* means wheel. The Easter Island legends say that magicians moved the statues by supernatural power (*mana*) and that the statues "walked" from the crater. The natives exhibit one big lava block as the first image that was made. It resembles a great lump of lava ejected by an eruption.

THE stone statues appear to have been a focal element in the natives' conception of the world. The statues were considered to have been born from the volcano, which was regarded as the womb of the earth. The Easter Islanders called the volcanic island itself *Pito Te Henua,* meaning "Navel of the Earth." *Mana,* the energy of life, was assumed to have its source in the flaming volcano, and it carried the statues through the air like flying birds. The most common bird on the island, the tern, actually nested in the crater. Man's life was considered a parallel to the bird's flight over sea and soil. Thus all the data—the tablets, the chants, the statues, the ceremonies—can be woven into a single carpet of images which presents a coherent, consistent explanation of the Easter Islanders' culture.

The key concept of this culture is the concept of death It is significant that the first immigrants under Hoatumatua came from an island named *Marae-toe-hau,* the literal meaning of which is "The Burial Place." This traditional migration from a "Burial Place" to an island of life, the "Navel of the Earth," was celebrated in many ceremonial acts.

There remains the most interesting question of all· Where did the ancestors of the Easter Islanders originate? Many legends of peoples in the Americas and in Polynesia tell of a Great Migration across the Pacific. When the first missionaries came to Mexico they were impressed by the similarity of pyramids they saw there to those of Egypt. The great 19th-century German explorer Alexander von Humboldt was struck by similarities in the language of Mexico and of ancient European cultures. Art objects typical of Melanesia and Polynesia have been found in Peru, in Chile and in Colorado.

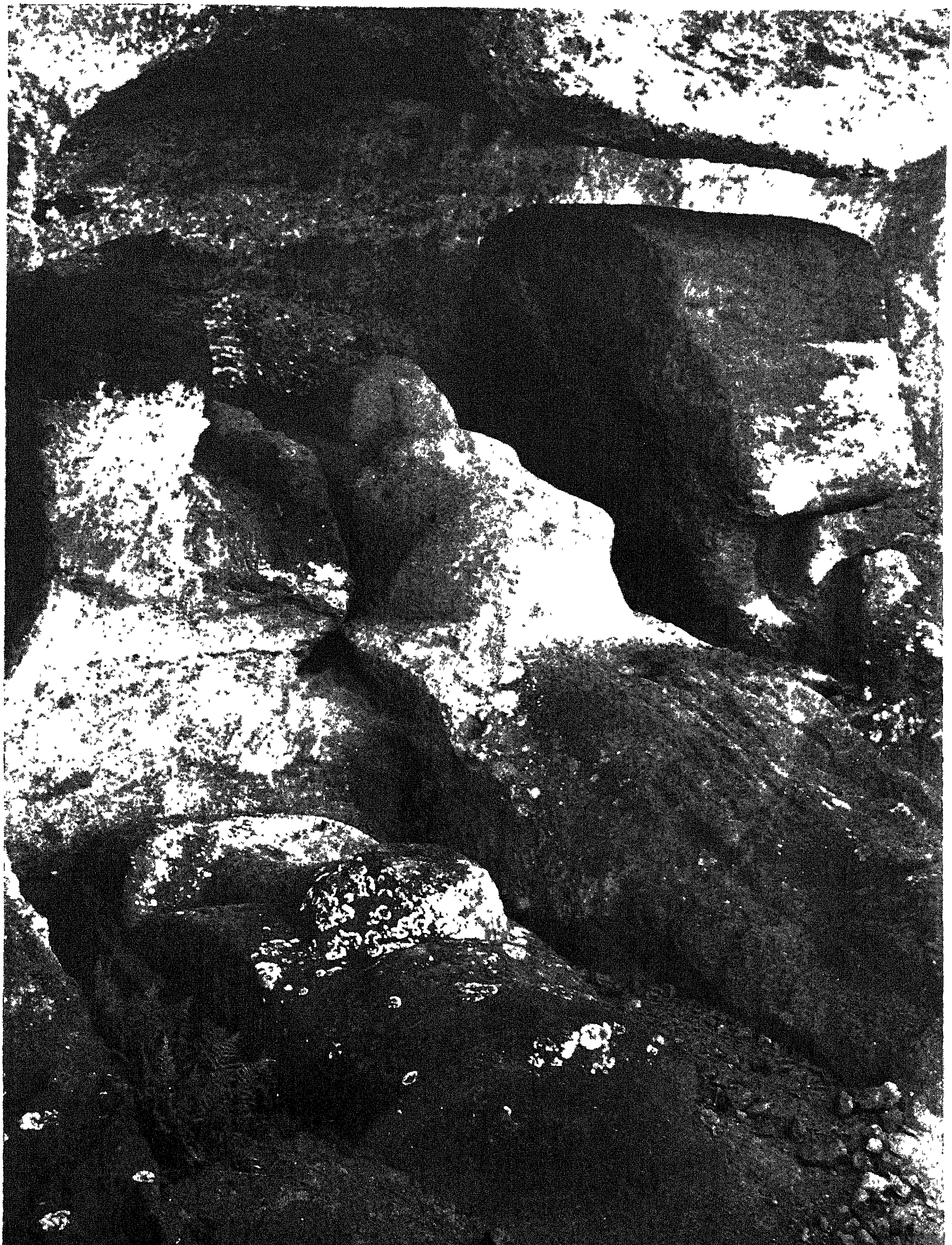
Where do the Easter Islanders stand in this presumed migration? A most important piece of evidence was discovered by Guillaume de Heveszy of France who detected likenesses between the hieroglyphics of Easter Island and an ancient script found in the Indus Valley of India. The Indus script, in turn, showed similarities to the picture writing of the Babylonians. Because the meaning of the Easter Island glyphs and of the Indus script was unknown, no definite proof of a cultural relationship could be established. But the translation of Easter Island's hieroglyphics now makes possible a direct comparison of these writings with those of other ancient civilizations, a study which led me to the discovery of a close correspondence between the glyphs of Easter Island and of Egypt.

Their symbols are often similar, not only in form but also in meaning. The similarities are so numerous and so detailed, in more than 80 glyphs, that they cannot be explained by chance. And since these similarities also refer to abstract concepts, they cannot be explained by common human experiences. Such concepts as God, good and to write, for instance, are represented by closely similar glyphs in both cultures. Some hieroglyphics similar in form have different meanings in Egypt and Easter Island, but these differences can be explained. For instance, an Easter Island glyph which is translated as *mata no te henua,* "the eyes of the earth," resembles an Egyptian hieroglyphic meaning grain of corn, or seed. "Eyes of the earth" can be explained as the seeds which, upon germinating, symbolize the opening of the eyes of Mother Earth, gazing at the sun.

MANY other symbols, such as the strange combination of sun bird and earth serpent, are found in the languages of Easter Island, Egypt and Mexico, and the symbol of the feather hat in Easter Island, Babylon and Mexico. The swastika, a common sign in all the ancient cultures of the Old World, also appears in a hieroglyphic on an Easter Island tablet and in the signatures of Easter Island's chiefs during the English expedition in 1774. Many other graphic symbols on Easter Island have counterparts in both the Old and the New Worlds. The similarities of form and meaning are not general, but of a most detailed kind, and they run through the whole pattern of the culture.

There is no reason to think that all ancient cultures lived in complete isolation; migrations, great and small, were possible and likely then as now. We know that famine and social motives drove tribes from land to land and that many of the ancient civilizations sent fleets across the oceans. The similarities we have been considering appear to confirm the theory of a cultural migration from the Old World to the New across the Pacific—with Easter Island as a possible bridge between the hemispheres.

Werner Wolff is professor of psychology at Bard College and author of the recent book Island of Death.



QUARRY on Rano Raraku contains several partly finished heads of the same kind found elsewhere on Easter Island. Other heads have been found in strangely inaccessible parts of the quarries. These and other facts led the author to believe that the location of the heads is in some way connected with volcanic activity.

NOW 76, BERTRAND RUSSELL has pursued theme of his book for some 35 years. His opening sentence: "The . . . purpose of this book is to examine the relation between individual experience and . . . scientific knowledge."

by Y. H. Krikorian

HUMAN KNOWLEDGE, by Bertrand Russell Simon and Schuster ($5 00).

THE aspect of science that appeals most strongly to the imagination is its power to build magnificent theoretical edifices upon the meager evidence accessible to human experience. From the limited data available on this planet, the astronomer infers vast universes. From the gross matter around us, the physicist derives the invisible world of atoms. From the remnants of ancient rocks, the geologist writes the history of the earth. From a scattering of human relics, the archaeologist reconstructs the civilizations of the past. To be sure, with the invention of such instruments as the telescope and the microscope, man has extended the range of his perceptions and experience; yet a wide difference remains between the world observable by the human mind and that constructed by the scientist's imagination. The abstractions of modern theoretical science—such concepts as instantaneous velocities, space-time, wave-particles—seem to have not the remotest relevance to everyday experience.

For nearly 35 years Bertrand Russell has relentlessly been exploring this problem of the relation between the world of our senses and that of scientific theory. He has discussed it in several books and many articles in philosophical journals. In "Human Knowledge" he returns to the inquiry with undiminished ardor. He announces in the first sentence: "The central purpose of this book is to examine the relation between individual experience and the general body of scientific knowledge." Russell has sometimes been accused of being a "flighty thinker" because he has repeatedly changed his stand on such questions as value, the nature of matter and the relation between mind and matter, but on the problem here discussed his approach on the whole has remained consistent and essentially unchanged

Russell is preëminently qualified to discuss this question. He has been one of the greatest figures in the development of mathematical logic. He is also an exceptionally competent observer of the developments in modern physics,

BOOKS

Bertrand Russell's latest inquiry into the relationship between theoretical science and the world of the senses

and sometimes a competent observer may have a clearer picture of what is happening than the participants in the game. Moreover, Russell is one of the keenest analysts among contemporary philosophers. He is a direct descendant of the long line of English empiricists—including Locke, Berkeley, Hume and Mill—who have been preoccupied with the nature, scope and limits of human knowledge. Russell is a worthy bearer of this tradition, and he brings to the task the tools of mathematics and mathematical logic—tools that the earlier English empiricists lacked

Unlike most philosophers, Russell places his problem in its empirical setting before attempting to come to grips with it. In masterly and succinct fashion he describes the state of contemporary knowledge in astronomy, physics, biology, physiology and psychology No less illuminating and valuable is his discussion of the nature and function of language, a field in which he has been a pioneer. He devotes special attention to the words and terms used to relate "individual experience to the socially recognized body of general knowledge." His analysis of proper names and his definitions of words such as truth, belief and knowledge are in the Russell tradition of brilliant clarification.

The general problem to which Russell addresses himself involves many specific questions. Russell discusses primarily three of these: What is the starting point of scientific knowledge? What is the nature of physical or scientific objects? How can we justify inferring scientific laws from a collection of data? The first question may be stated in another way: What are the most fundamental data from which scientific constructions are made? It would appear that we should be able to answer this without much difficulty, but the more the question is examined the more complicated it becomes The so-called hard facts of common-sense experience and especially of science are actually a tissue of inferences. To arrive at the core of fundamental data on which knowledge is based, philosophers and scientists have followed the method of progressively stripping away the inferential elements. From David Hume to Russell, this search has led many empiricists to the conclusion that the rock-bottom basis of knowledge is sensation. As Russell puts it, "Only sensations and memories are truly data for our knowledge of the external world," and memories, in Russell's view, have their origins in sensations. By sensations Russell means our qualitative experiences, such as color, sound, touch. If I say, "I see a red apple," I may be making an incorrect inference, for the object may not be an apple. But if I say, "I have the sensation of red," I cannot be mistaken, for at this level the statement is free of interpretation, except insofar as I have used an arbitrary term, red, to name the sensation.

For Russell, then, sensations are the basic data of knowledge. When sensations are amplified by what he calls animal inference, they then become perceptions. By animal inference, Russell means the automatic, unconscious linking of a sensation to an intimately related idea The beginnings of such inferences are found in the higher animals. The perception of a building, of a person, or of the sun involves more than simple sensation. The inferential process is always present The building I see is something to live in, the person I see is a friend, the sun I see is a source of light. Because an inference may be incorrect, perceptions are always open to error In a previous book, *An Inquiry into Meaning and Truth,* Russell asserted that "a man possessed of intellectual prudence will avoid such rash credulity as is involved in saying 'There's a dog,'" for the inference that one is seeing a dog may arise from an artificial excitation of the optic nerve, a blow on the head, or some other deceptive circumstance.

Moreover, sensations and perceptions, says Russell, are purely subjective. When I see a building, a person or the sun, these objects, with all their relations in space and time, belong to *my* world of experience, to *my* mind. Their supposed objectivity and independence are not tenable. Russell maintains that when a physiologist observes a living brain, he is observing in fact only his own brain This startling statement, to which many of Russell's critics have strongly objected, is quite tenable if one accepts Russell's basic premises. We need not labor the arguments for the subjectivity of perceptions, for they have a long history.

If every perceived object belongs to my private world, how do I escape the conclusion that the world exists only in my mind? Hume started, as Protagoras had started much earlier, with the subjectivity of perceptions, and got no further. Russell refuses to accept this impasse. In an exciting chapter on the question, he argues that partial skepticism, such as the denial of physical events which no one has experienced, is logically indefensible. Like René Descartes, he likes to stretch to the breaking point our faith in the objective, external world, but before the actual break—again like Descartes—he tries to save us from utter skepticism.

In place of Descartes' God, Russell brings to our rescue his postulate of causality. Our perceptions, though themselves private, must have a causal basis, he says. There must therefore be an external world. The causal bases of our perceptions are physical "objects" such as electrical discharges, sound waves, and so on A flash of lightning is described by a physicist as an electrical discharge which propagates electromagnetic waves. When these waves happen to enter a human eye connected with a human brain, the person to whom the brain belongs "sees" the flash. His perception of the flash with all its qualities is private to him, but its causal basis is not.

Thus causality demands a physical world as the basis of our perceptions. Of the nature of this physical world, Russell observes at the beginning that physical objects are inferred and not observed. He says. "I should define [a physical event] as an event, which, if known to occur, is inferred." A mental event, on the other hand, is defined as "one with which someone is acquainted otherwise than by inference." Russell rejects the "common sense" view that the sun we see is the same as the sun described by the astronomer. The perceptual sun is a round area of brightness; the physical sun is a complex of unperceived electrons, protons and other particles. What we know about physical objects is that they have structure. They are not, like Immanuel Kant's things-in-themselves, totally unknown to us, though our knowledge is incomplete. From the fact that the perceptual sun looks round, we are entitled to infer, says Russell, that the physical sun also is round. On the other hand, the fact that the perceptual sun appears bright does not imply that the physical sun is bright. Brightness is a qualitative, not a structural property. Qualities are characteristic of perceptual objects; structure, of physical objects.

We cannot say that the physical sun either is or is not bright; no statement of qualitative properties can be made with respect to physical objects. All we know about them is their structure.

The language most appropriate to describe what we learn of physical structures is that of mathematics. The structure of physical objects must satisfy mathematical and logical laws. When a physicist is asked, "What is an electron?" he describes it in mathematical terms, and regards this description as sufficient. In modern analysis the ultimate particles of matter fade away into abstractions definable only in terms of mathematical functions that require a special algebra. Similarly other fundamental concepts of physics, such as space, time and causality, are expressed by mathematical equations. Russell emphasizes this mathematical structure, and its extreme remoteness from our everyday experience.

Nonetheless, the structure of a physical object must be so interpreted as to yield results that can be confirmed or confuted by observation. Even when physics is so abstract that it becomes a branch of mathematics, it must remain relevant to observable conditions at some point. In the last analysis, physics seems to need only the concepts of energy, electrical charge and space-time coordinates. But energy, though highly abstract, is a generalization arrived at by concrete experiments. Electricity, though a quantitative concept, is not just any quantity, but that quantity measured by electrical instruments. Physics is a verifiable science, and its most abstract concepts must have relevance to our experience.

Russell now arrives at a discussion that is the most valuable part of his book· on probability and on the validity of scientific inferences. How can we justify deriving laws in science from mere collections of data? In other words, is it justifiable to establish universal laws by the process of induction, which can give us only probable inferences? The usual justification of induction is in terms of simple enumeration based on the repetition of events. It is maintained, for example, that from our knowledge of the past mortality of human beings we are entitled to say it is probable, though not certain, that Mr X will die. Russell contends, however, that such an inference cannot be validated by experience alone; its fitness and probability rest on certain basic postulates that come before experience. These postulates can neither be established by logic nor discovered by experience; yet, as Russell maintains, they must be entertained. He offers five of them: the postulates of quasi permanence, of separable causal lines, of spatio-temporal continuity in causal lines, of structure and of analogy. These postulates justify rational expectations, but expectations short of absolute certainty. They have a subjective as well as an objective meaning: subjectively, they assert that certain expectations have rational credibility, objectively, they assert that certain events happen in most cases. What is most important about these postulates is that taken collectively they appear to justify inductive inferences.

Russell's claim may be illustrated by considering one of his postulates. The postulate of causal lines asserts that a series of events in time is so related that, "given some of them, something can be inferred about the others, whatever may be happening elsewhere." For example, when one sees a number of stars, he attributes the multiplicity of his visual sensations to the multiplicity of stars as the causes. Again, when he sees a table or a chair, he assumes that there is a causal line from each of these objects to the eye. That there are such causal processes cannot be established by logic nor fully verified by experience, yet this assumption, in Russell's belief, is one of the fundamental postulates of science. He says. "It is in virtue of the truth of this postulate—if it is true—that we are able to acquire partial knowledge in spite of our enormous ignorance."

Such is Russell's argument. There are basic controversial issues involved in it. To begin with, Russell's contention that sensation is the primitive datum of knowledge is highly debatable. It is true that any given scientific investigation has a starting point; but the starting point of science is not the datum of mere immediacy, but rather the rich experiences of everyday life. We neither require nor possess absolutely simple data. The aim of science, one might say, is not primarily construction from simple data, but rather reconstruction of the given experience. And this reconstruction involves both analysis and synthesis. While in any reconstruction of experience a certain group of data is given, it is given for the construction in question and is determined by the point of view from which the reconstruction is formulated. In such a reconstruction, sensations are as much the results of analysis as they are the assumptions used in synthesis.

Again, Russell's subjective theory of perception is open to serious doubt. His subjectivism is based primarily on the interpretation of experience by the classical empiricists. But is this interpretation necessary? A more experimental approach to the nature of experience, which Russell occasionally suggests, would indicate that there is an essential identity between the meaning of experience and the meaning of experiment. And if experience is experimental in all its phases, what is experienced by one may be shared by all. Once we reject Russell's subjectivistic premises, there is no need to assert two exclusive and rather dissimilar worlds—the perceptual and the physical. Because a scientist is interested in the quantitative relations of an object and thus finds it useful to di-

rect his attention to these relations exclusively, it does not necessarily follow that the qualitative aspects of the situation are less real than its quantitative aspects, let alone wholly unreal.

As for Russell's postulates, they are significant in emphasizing the non-empirical aspects of scientific procedure. With some important differences, these postulates remind one of Kant's *a prioris*. Russell, it seems to me, could have emphasized much more than he does their functional role. Since in certain parts of his discussions he seems to lean toward a pragmatic theory of knowledge, he would have been justified in such a formulation. While it is true that these postulates cannot be established with any finality by logic or experience, yet they are fruitful regulative principles to guide scientific activities.

Though I find myself in disagreement with several of its conclusions, I believe "Human Knowledge" to be a book of great value. It restates freshly the traditional problems of philosophy; it shows how to develop a philosophy on the basis of the significant findings of modern physics; it illuminates the complex logical structure of scientific theories. It is not only what Russell says but the way he says it that makes the book valuable. His philosophic temper is charmingly reasonable, his style, as usual, lucid and incisive, though its lucidity often glosses over the complexity of his ideas. At difficult points a dash of wit relieves the reader's strain. To follow, step by step, Russell's keen analysis of human knowledge is a rare intellectual pleasure.

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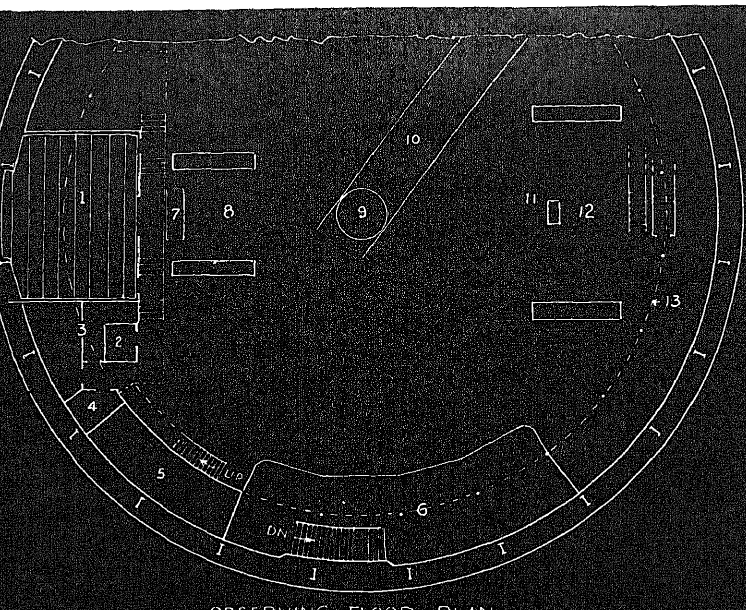
A SOURCE BOOK IN GREEK SCIENCE, by Morris R. Cohen and I. E. Drabkin. McGraw-Hill Book Company ($9.00). An excellent addition to the Source Books in the History of the Sciences series. It contains excerpts from the great works on mathematics, astronomy, geography, physics, chemistry and chemical technology, geology, meteorology, biology, medicine and physiological psychology. There is also a useful bibliography. The scope is so wide that one can easily excuse even the more striking and painful omissions: thus, for example, problems and paradoxes of the infinite and infinitesimal are excluded on the ground of their "predominantly philosophic character."

PHYSICS AND POLITICS, by Walter Bagehot. With a new introduction by Jacques Barzun. Alfred Knopf ($2.50). This famous 19th-century essay, now reissued with an interesting introduction by Jacques Barzun, applies the principles of natural selection as defined by Charles Darwin to the evolution of social institutions. It has nothing to do with physics, although physicists, like everyone else, can learn a great deal from it; and the word politics must be understood as referring to the social sciences rather than to the shenanigans of statesmen or ward heelers. In his brilliant, ironical style Bagehot gives a lucid analysis of the various forces which make for social change and innovation on one hand and for permanence and stability on the other. His book is a pioneer work in social psychology, written by one of the first-class intellects of the Victorian era.

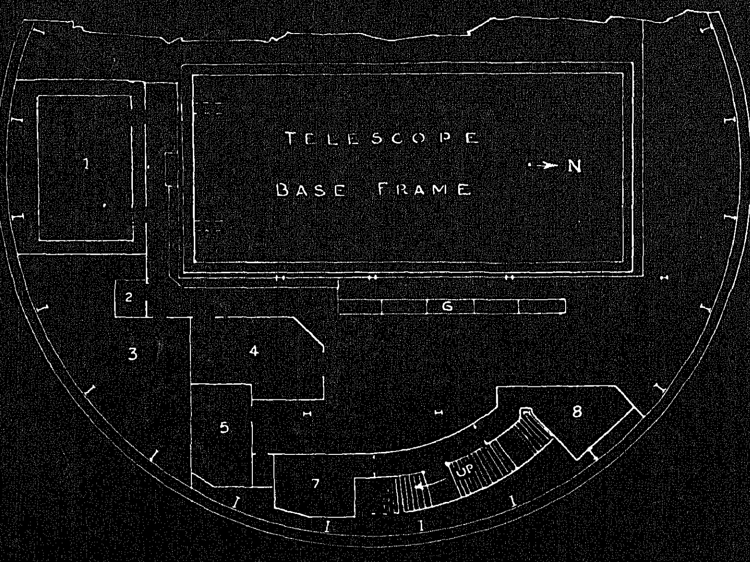
APPLIED MATHEMATICS FOR ENGINEERS AND SCIENTISTS, by S. A. Schelkunoff. D. Van Nostrand Company ($6.50). A clear, well-balanced mathematical text, the latest addition to the useful Bell Telephone Laboratory Series conceived primarily to meet the needs of communication engineers. What distinguishes the book and deserves notice is the amount of space allotted and the careful treatment given to special functions, particularly Bessel and Legendre functions. It is evident from books of this kind that the easy and prevalent notion of the engineer as one who can just about use a slide rule and who thinks of an integral as a number to be looked up in a table is rapidly becoming a myth. Whether or not the myth ever had substance, it is obviously untrue today. It is getting to be as hard to distinguish between a research engineer and a "scientist" as to keep track of the thin, fading line between "pure" and "applied" science. There is obviously no point in turning your good-for-nothing son into an engineer; once again there is nothing left for him but the law.

THE UNIVERSE AND DR. EINSTEIN, by Lincoln Barnett. William Sloane Associates ($2 50). A brief, popular exposition of the quantum theory and relativity by a former editor of *Life*, based on a series of articles which appeared in *Harper's* last year. The publisher's blurb describes the attempt of the book as the "most brilliant in our time," which is pretty silly even for publishers' blurbs. While the author, as long as he resists an unfortunate temptation to philosophize, writes clearly, there is nothing in the book which has not been handled more effectively by a number of earlier writers, including Hans Thirring, C. V. Durell, Bertrand Russell, James Jeans and Arthur Eddington. The book is not distinguished by fresh insights or original analogies to help illumine the shadowy concepts of modern physics. The subject remains difficult. Nevertheless the attempt to elucidate it in the language of laymen continues to be an eminently worthwhile journalistic enterprise, and Mr. Barnett's account is sounder and more illuminating than most.

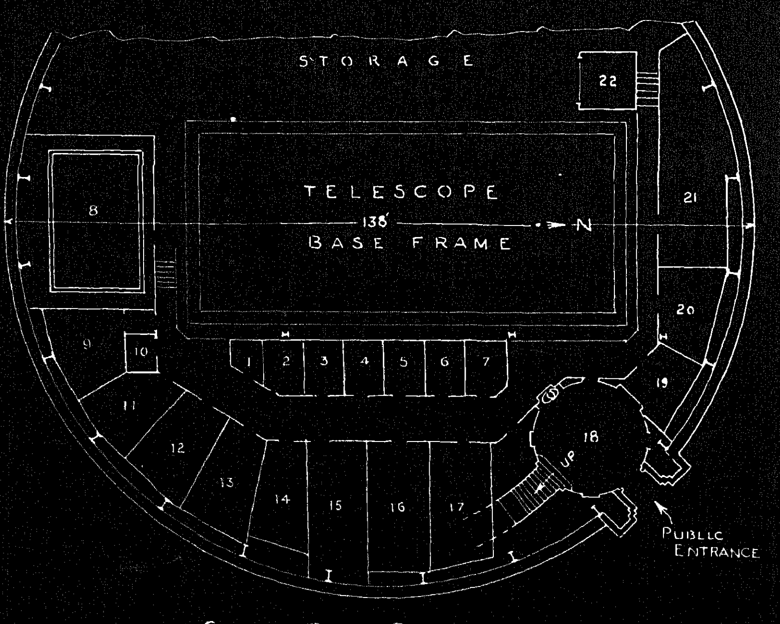
J. R. N.



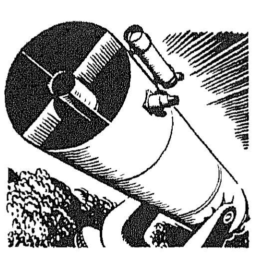
OBSERVING FLOOR PLAN



MEZZANINE FLOOR PLAN



GROUND FLOOR PLAN



Conducted by Albert G. Ingalls

ALL amateur astronomers doubtless hope some day to make a pilgrimage to Palomar Mountain Observatory and see the 200-inch telescope. Before planning such a trip they will want a specific answer to the question "If I should go, how much of the real inside stuff will I see?"

The policy of the observatory is that of the late George Ellery Hale, its founder. Dr. Hale was a man who liked amateurs. The observatory's policy is to admit the public ungrudgingly, up to the point where this begins to interfere with the astronomical research for which the observatory was built.

Obviously not all of the observatory can be shown to tourists, since they arrive at a rate of 100,000 a year Some of the tourists, however, are amateur astronomers. Cannot at least these be shown the whole installation? Unfortunately if only 1,000 amateurs arrived at Palomar every year, wishing to be shown everything and to talk with the staff, this might interfere with the astronomical work more than the visits of 99,000 tourists.

So the amateur astronomer should not count on seeing more than the most interesting third of Palomar—the mounting and tube of the 200-inch telescope. He will not see the interesting rabbit warrens on two broad floors beneath the observing floor of the 200-inch. The present article therefore will attempt to describe this forbidden region. Nowhere has it yet been systematically described with plan diagrams.

The visitor enters the dome where Russell W. Porter has lettered in the words "Public Entrance" in the drawing labeled "Ground Floor Plan" at left. In vestibule 18, after examining a bronze bust of Dr. Hale, he will turn to the left and climb 26 feet in two flights of stairs, emerging 5,572 feet 6 inches above sea level in the ample visitors' gallery. This is a completely enclosed area of the concrete main observing floor.

Here in full view, only 40 feet away from the gallery, stands the 200-inch telescope. It towers so high that the visitor feels he is almost under it. This vantage point, however, offers the best view of the telescope

Visible from the visitors' gallery is the short stairway approach to the coudé spectrograph room shown at 1 in the drawing labeled "Observing Floor Plan."

HE AMATEUR ASTRONOMER

The room also appears at left in the elevation drawing below. What appear to be stairs in this room are concrete platforms, each 22 inches higher than the last This large room will eventually contain four Schmidt spectrographs which are now being made.

The optical train from star to spectrograph film is as follows: to the 200-inch mirror; thence upward to a hyperboloidal convex secondary mirror near the top of the telescope tube, thence downward to a flat mirror opposite the declination axis, thence diagonally downward through the hollow polar axis south bearing (*indicated as P A on the elevation drawing*), next, to a collimating mirror near the exterior wall of the spectrograph room, thence by reflection back to a diffraction grating near the port through which the beam entered the room, thence back to the left through the correcting plates of any chosen one of four large Schmidt cameras (which have 20-inch, 30-inch, 36-inch, and 48-inch primaries), thence to the Schmidt primaries, and finally to the photographic film at the Schmidt focus With the faintest stars the spectra will be spread to only one inch in length, on the brightest stars to an equivalent length of 12 feet.

At 2 on the observing floor plan is a small automatic elevator that gives the staff quick access to ground floor, mezzanine, observing floor, and balcony.

At 3 is a plate-change room and at 4 is a rest room.

At 5 is a repair shop. Backing it up is a machine shop at the nearby observatory power house, and the larger shop on the California Institute of Technology campus in Pasadena.

At 6 is the visitors' gallery.

At 7 is the computer. It stands on a raised platform near the right ascension drive. A coffinlike box that encloses it protects delicate mechanisms which change the speed of the sidereal drive to compensate automatically for angular variations in atmospheric refraction, structural deformations of the telescope. errors in the gears and elsewhere The box also contains an automatic mechanism for keeping the dome opening in line with the telescope

At 8 is the double south pier of the telescope (*see elevation drawing*).

At 9 is a hydraulic hoist also shown in the elevation. This is for raising equipment to the Cassegrain focus of the telescope, also as a working platform.

At 10 is a broad-gauge railroad track on which the aluminizing chamber unit may be drawn from its storage position at the side of the floor to the center under the mirror.

At 11 is the complex control desk.

At 12 is the double north pier of the telescope

At 13 is the dome balcony, which rotates with the dome—so smoothly that riders on it, not realizing they have been put in motion, exclaim, "The telescope is turning!"

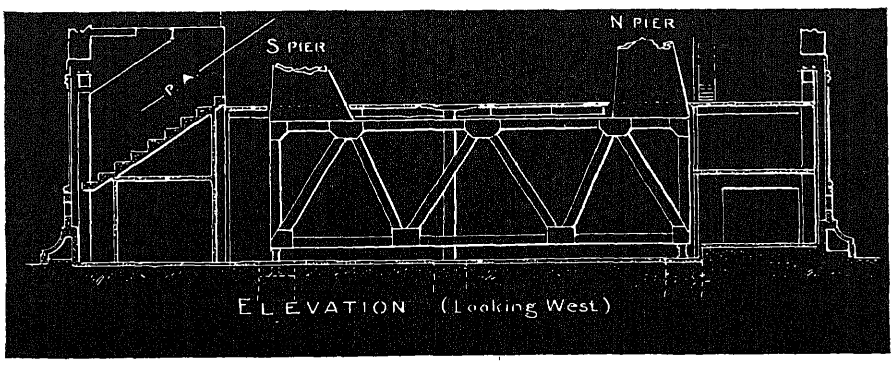
On finally leaving, the visitor will pass the mezzanine floor, perhaps without being aware that it is there. In the vestibule on the ground floor he may not even note an inconspicuous door leading to the ground-floor spaces. No door is shown on the plan drawing, but the door that is there is a fact, not a theory, and it is kept locked. However, for the purpose of this itinerary, let us not descend from the visitors' gallery but, instead, use Porter's master key to all the locks at Palomar, and walk to the observing floor through a door in the side of the gallery. Then:

At 1 is to be a physical-measurements room.

At 2 is an automatic elevator.

At 3 are switchboards for the main electrical distribution. There are also transformers, motor generators, and a battery-charging panel.

At 4 is the constant-frequency room. Here the electric drive of the telescope is initiated and controlled in frequency by a vibrating-string Warren time standard within an accuracy of less than one



Structure of three stories within the dome of the 200-inch

tenth second a day. On a central table stands a metal tripod a foot high. From it is suspended a wire a few inches long and held taut at the bottom. Attached crosswise halfway up the wire is a small permanent magnet, one end of which projects into a pickup coil connected to the grid of a vacuum tube, the other into a driving coil connected to the plate of the same tube. The wire is tightened from below to vibrate at 60 cycles per sidereal second. The current generated by this unit, its blurred bowstring vibrating softly throughout the night, is amplified to run the one-twelfth horsepower driving motor of the telescope.

At 5 is the storage battery room. If the Diesel motor generator at the observatory power plant should fail, the batteries would automatically take over. (There is no power-line connection between Palomar and the outside.)

At 6 are the telescope relay panels, a maze of apparatus.

At 7 and 8, opening only on the outside stairway to the visitors gallery, are rest rooms.

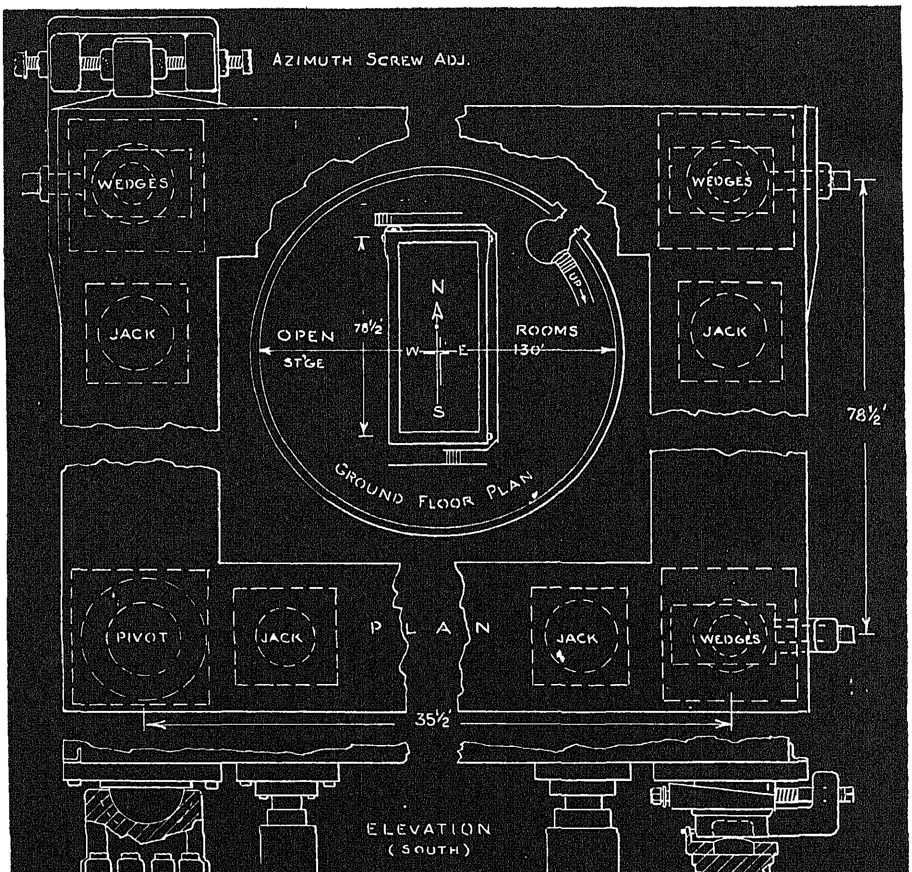
In the open on the same mezzanine floor are the oil tanks and pumps that constantly force lubricating oil compounded with rust inhibitor, at the rate of two and a half gallons a minute and at 290 to 518 pounds per square inch pressure, through the oil pads of the telescope bearings, so that the telescope floats on a .003- to .005-inch-thick film of oil.

Finally we come to the ground floor where the astronomers work and rest.

Room 1 is for storage.

Rooms 2 to 7 are astronomers' working offices.

Room 8 is for physical measurements.



Arrangements for adjusting the 200-inch in altitude and azimuth

Room 9 is for photographic developing.

At 10 is the elevator.

At 11 and 12 are large and wonderfully equipped darkrooms

At 13 is the ammoniating room for plates, and Room 14 is for plate storage.

At 15 is the fan room with air-conditioning machinery, a refrigerating compressor (120,000 B.T.U. per hour).

Room 16 is to be a chemical laboratory, and Room 17 a physical laboratory.

At 18 is the entrance vestibule.

At 19 is a rest room.

At 20 is the staff's library.

At 21, spacious and comfortable, is the lounge, an all-night clubroom for relaxa-

tion between astronomical labors aloft and for conversation.

The fabricated steel telescope base frame (*see ground floor plan*) is 78½ feet long, 35½ feet wide and 22 feet high (the measurements are made over beam centers). It resembles a span from a through-type railroad bridge, and a check shows that it is about five feet wider and five feet lower than such a bridge.

It is fun to crawl from the adjacent storage space back into the dusty, dim places behind and beneath this base frame, explore its legs, and study the provision for adjusting the telescope in altitude and azimuth. Since several to whom these outsized adjustments were described have suspected that their own legs were being pulled ("Too big a telescope for that sort of thing"), Russell Porter was invited to make a plan and elevation drawing of the adjusting facilities:

The arrangements differ in no basic way from those under amateurs' telescopes. For azimuth adjustment there is a 12-inch pivot ball at the southwest corner of the base frame, and under the remaining corners are 24-inch rolling balls of tool steel. For altitude adjustment there are jacks and wedges. Only one half of the 12-inch pivot ball is needed or used (*see drawing on opposite page*), while the 24-inch rolling balls, since they need roll only an inch or so, are cut away to posts six and a half inches in diameter with spherical tops and bottoms.

The base frame is restrained from rolling all over Palomar by the azimuth screw adjustment at the northwest corner of the base frame. Byron Hill, the superintendent of construction at Palomar, says it was easy with his transit to spot the base frame at the outset within one minute of arc of the earth's meridian plane (one eighth inch, plus or minus). A long-handled wrench permits one man to move the 1,000-ton weight and complete the adjustment by means of the push-pull screws shown on the plan.

The four base-frame underpinnings rest on concrete piers in holes excavated 25 feet in the Palomar granite This was done in order to diminish transmission of vibrations from the piers of the dome, which are only four feet deep.

The altitude and azimuth adjustments may be used again in the future. Palomar Mountain is a part of a fault block of the earth, about five by 15 miles in dimensions, with the active Aguanga Fault about two and a half miles to the northeast, the possibly active Elsinore Fault five miles to the southwest. As this fault block, which might be regarded as the telescope's lower "base frame," may be disturbed from time to time, its own azimuth and altitude angles may change a little. Readjusting the telescope after such events will not be a difficult job.

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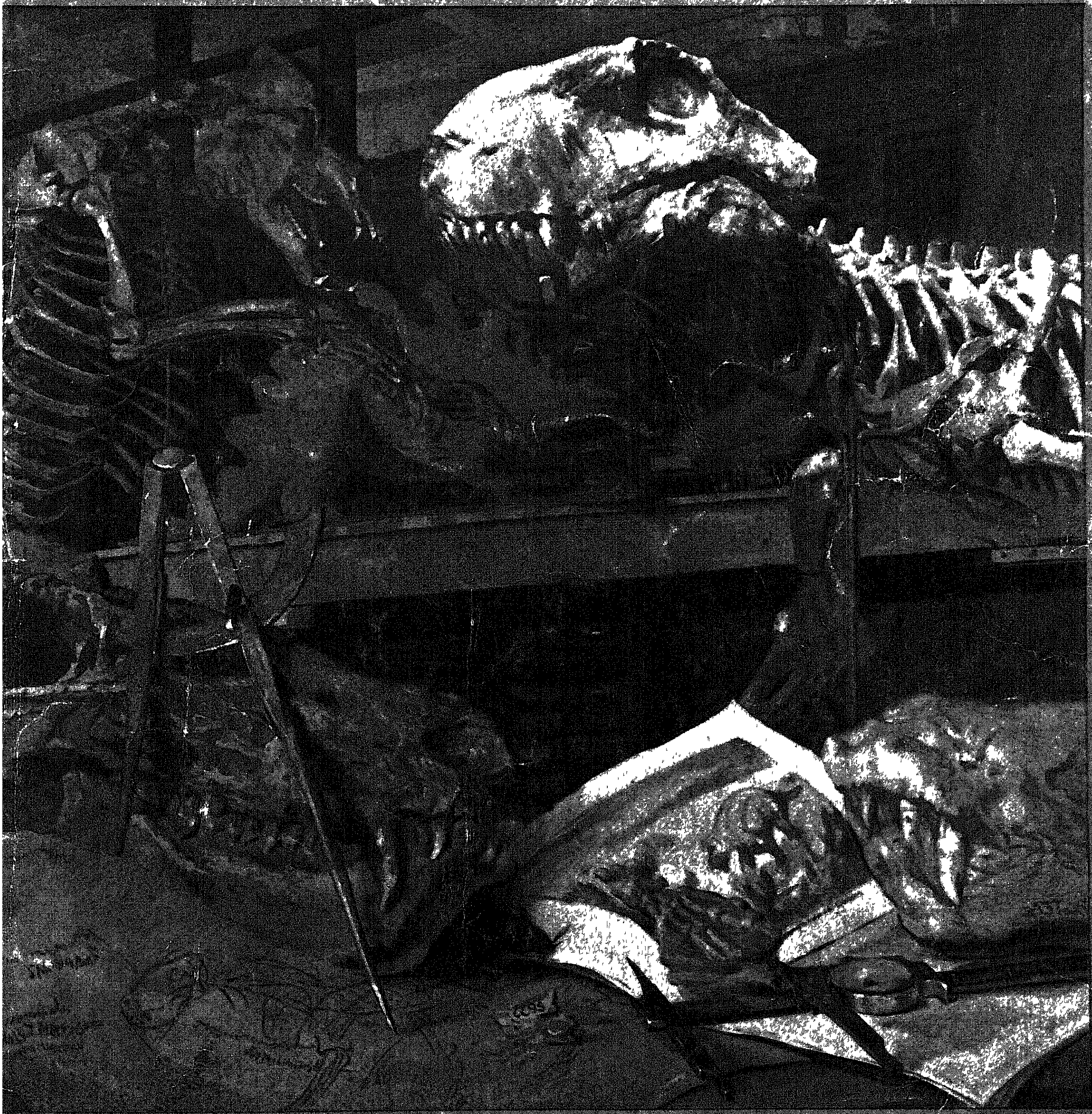
ISLAND OF DEATH Werner Wolff, J. J. Augustin, 1948.

SCIENTIFIC AMERICAN



ANCESTRY OF MAMMALS

FIFTY CENTS

March 1949

New RCA 16-inch direct-view television tube fills gap between popular 10-inch tubes and the projection-type receivers.

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The screen on which you are accustomed to seeing television is the face of an electron tube—on which electrons "paint" pictures in motion.

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Working to give you *bigger*, brighter pictures, RCA engineers and scientists developed a new way to make large, direct-view television tubes. They found a method of "welding" large areas of glass and metal... while keeping a vacuum-tight seal!

Using this development—ideally suited to mass production—RCA can now build television tubes of light, tough metal... using polished glass for the face, or "screen."

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Development of this new television tube is a continuation of *basic television research* which began at RCA Laboratories. Such leadership in science and engineering adds *value beyond price* to any product or service of RCA and RCA Victor.

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Examples of the newest advances in radio, television, and electronics—in action—*may be seen at RCA Exhibition Hall, 36 West 49th Street, New York. Admission is free. Radio Corporation of America, Radio City, New York 20.*

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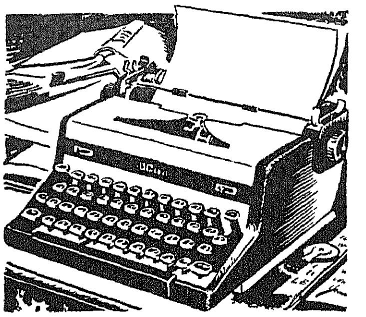
LETTERS



Sirs.

Congratulations on the article, "The Oedipus Myth," by Erich Fromm, in your January issue. It makes a contribution to many d[illegible]nt aspects of social and humane [illegible]ues. For one thing, it enriches twice-told tales by seeing meanings in them which still have bearing. The Broadway play *Medea* would have struck its audience as less remote—as less merely "a fine vehicle for Judith Anderson" as one friend put it—had it been seen as dealing with the undying conflict of matriarchal-blood and patriarchal-authority themes.

For another thing, the article's mode of analysis renews our interest in the potentialities of understanding certain historical developments in terms of the changing role of the sexes. This is neither the economic struggle, as Engels was tempted to see it in *The Origin of the Family*, nor the sex struggle for access to the mother, as Freud so largely saw it; but as Fromm sees it, sex relations both reflect and perpetuate the particular authority structure, the mode of thought, indeed the whole quality of the society. One might ask, for example, whether the United States is actually as "matriarchal" a country as observers often assert when so many of our human relations resemble Creon's methods, and even style of speech, rather than Antigone's. In the American middle classes, children are often not so much respected for their individuality—as one would find in some more "matriarchal" cultures—as deferred to for their nascent role as arbiters of the new and carriers of the family's hopes for advancement.

Finally, the article suggests a perspective on the future. It grants the need and value of an advance from the limited blood ties of the matriarchal level of social organization to the broader, and therefore necessarily more abstract, ties of economy, polity, and ideology which are associated with the change to a more patriarchal society such as our own. But it also asks: What would our society look like if it succeeded, without organizational regression, in recapturing something of the outlook—humane, concrete, equalitarian, and sensitive—which Fromm describes as typical for matriarchy?

DAVID RIESMAN

Law School
Yale University
New Haven, Conn.

Sirs:

In comment on Erich Fromm's article, "The Oedipus Myth":

The ideas set forth are of utmost importance, not because they present a plausible and, to the anthropologist, a consistent reinterpretation of the Oedipus theme in our society, but because of the view they hold for man's destiny.

Freud doomed man to his instincts and, if traced far enough, also doomed man to conform to the society in which he was born. Not only is this view a static one, inconsistent with progress—and man has progressed—but it presents a situation in which there are no outs for man and little hope for the future. Fromm makes the point that man's salvation lies in himself and that he is not bound by man-made rules. The implication of this line of reasoning will not be fully appreciated for some time to come.

There are other important aspects of Dr. Fromm's article which your readers can ferret out for themselves, and I hope you continue to carry articles by him.

E. T. HALL, JR.

Bennington College
Bennington, Vt.

Sirs:

In your December article on alcoholism from the biochemical standpoint, by Roger J. Williams, the author moves from individual human variation in sus-

Scientific American, March, 1949. Vol 180, No 3. Published monthly by Scientific American, Inc., Scientific American Building, 24 West 40th Street, New York 18, N. Y.; Gerard Piel, president; Dennis Flanagan, vice president, Donald H. Miller, Jr, vice president and treasurer. Entered at the New York, N. Y Post Office as second-class matter June 28, 1879, under act of March 3, 1879. Additional entry at Greenwich, Conn

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What GENERAL ELECTRIC People Are Saying

WILLIS R. WHITNEY

Honorary Vice President;
First Director of Research Laboratory

RAW MATERIAL IS INFINITE: All this (the new Laboratory) is a simple logical outcome of industrial scientific progress apparent all along. It is nothing compared with the opportunities of the future.

I see all these youngsters in research around me now, and think of the prospects they have before them for understanding and harnessing nature. The stock of raw material is really infinite. The difficult thing is to find out how to make it useful. What most people don't see, can't seem to see, is that if you have an infinite supply, then any part of that infinity is infinite, too. Research is like a tree that broadens out as we look up from its base.

Truth is that which someone discovers and describes as well as he can so that someone else can attempt to reach the same goal, and if there is repeated success by others, then we can say we have a grasp on some portion of the infinite.

Opening of first section, new Research Laboratory, Schenectady, N. Y., December 2, 1948

★

E. F. W. ALEXANDERSON

Consultant, General Engineering & Consulting Laboratory

RADIO ECHO: Radar is an example of the type of invention which appears inevitably at a time when there is a demand for it. The scientific background was there, and the demand for it was War, or preparation for War. It is impossible to say who invented it first; it sprang into existence in several countries simultaneously. I am definitely not one of those who claim to have invented radar, but I can tell the story of how I came pretty close to it ten years earlier—and missed it.

There was a demand for a method to measure the height of an airplane over the ground, and experiments were made by ground echo. There were several—and I was one of them—who had the idea that the nearness to the ground would modify the electrostatic capacity between a radio antenna and the airplane. This idea proved to be impractical, but on experimenting with it, I stumbled on another idea by accident.

The apparatus was installed on an airplane, and I tried to find changes of the antenna tuning due to the proximity of the ground. The expected effect was not there, but instead I observed a periodic increase and decrease of the instrument indication when the airplane was continuously ascending or continuously descending. This gave me the idea that we had a standing-wave pattern due to the echo from the ground. I then looked for the altitude distance between successive maxima and found that they were exactly half a wavelength of the radio frequency which we used for measurement. Then I told my collaborators: "Now I am going to tell you the successive altitude levels if you observe the barometric altimeter and cover it so that I cannot see it." We went up and down several times, and I called out the altitude levels correctly.

Royal Technical University, Stockholm, Sweden, October 7, 1948

★

C. G. SUITS

Vice President and Director of Research

ENDLESS FRONTIER: It is clear that the United States is acquiring a great stake in the future of scientific progress. The stage is being set with great care, most of the actors know their lines and some exciting scientific drama is in the making. That American scientists will play a leading part in World Science is very clear, for these great strides forward have been made against a background which has been largely stationary or receding, in the rest of the world . . .

No clairvoyance is required to see that American science is acquiring tremendous momentum. The next few years will certainly bring a flood of new scientific facts to replenish the stockpile from which we drew so heavily for the defense of the nation a few years ago. In spite of the tremendous efforts which have gone, and are going, into research, science still presents an endless frontier to challenge future generations of pioneers.

Edison Pioneers, East Orange, N. J. February 11, 1949

★

H. A. WINNE

Vice President in Charge of Engineering Policy
Chairman of Nucleonics Committee

NO UNREASONED FEAR: How many of us really know what happens—from the standpoint of physics and chemistry—when we light a fire or when we turn on an electric lamp? Yet we know what fire and electricity can do; we know their possibilities and limitations; we know how to use and control them. We realize their possibilities for harm—their dangers—but we know how to protect against them, and we do not have an unreasoned wild fear of them.

The same can be true of atomic energy, and each of us can then draw his own conclusions as to its probable economic and social effects.

Syracuse University Alumni Association, October 21, 1948.

You can put your confidence in—

GENERAL ELECTRIC

ceptibility to what he calls "wide differences among racial and national groups." He then goes on to stereotype American Indians and Irish as high in susceptibility, and Jewish people as being relatively non-susceptible. My point is that his theory, which seems plausible enough in application to individuals, is anthropologically unsound in its *simpliste* racistic application to groups

Racistic explanations historically have made their points by eliminating the effects of culture on human behavior. Dr. Williams should consult Horton's "The Functions of Alcohol in Primitive Societies: A Cross-Cultural Study" in the *Quarterly Journal of Studies on Alcohol* (Vol. 4, No. 2; September, 1943) Granted *individual* variations, the social and cultural function of alcohol (or peyote, betel nut, kava, nicotine) introduces a selective factor which influences any statistical data. Obviously, before one can weight a factor, one must isolate a factor The acculturated Indian, Irish *et al*, remain unknown quantitatively and qualitatively to the biochemist. So long as this is true, biologistic science cannot scientifically comment upon them as groups in instances where socially and culturally determined behavior is involved.

What the anthropologist would say is the following. Human groups *are* human This means they are social and cultural in nature and in operation, and cultural behavior is *not* biologically determined.

MARVIN K OPLER

Chairman
Department of Anthropology
and Sociology
Occidental College
Los Angeles, Calif.

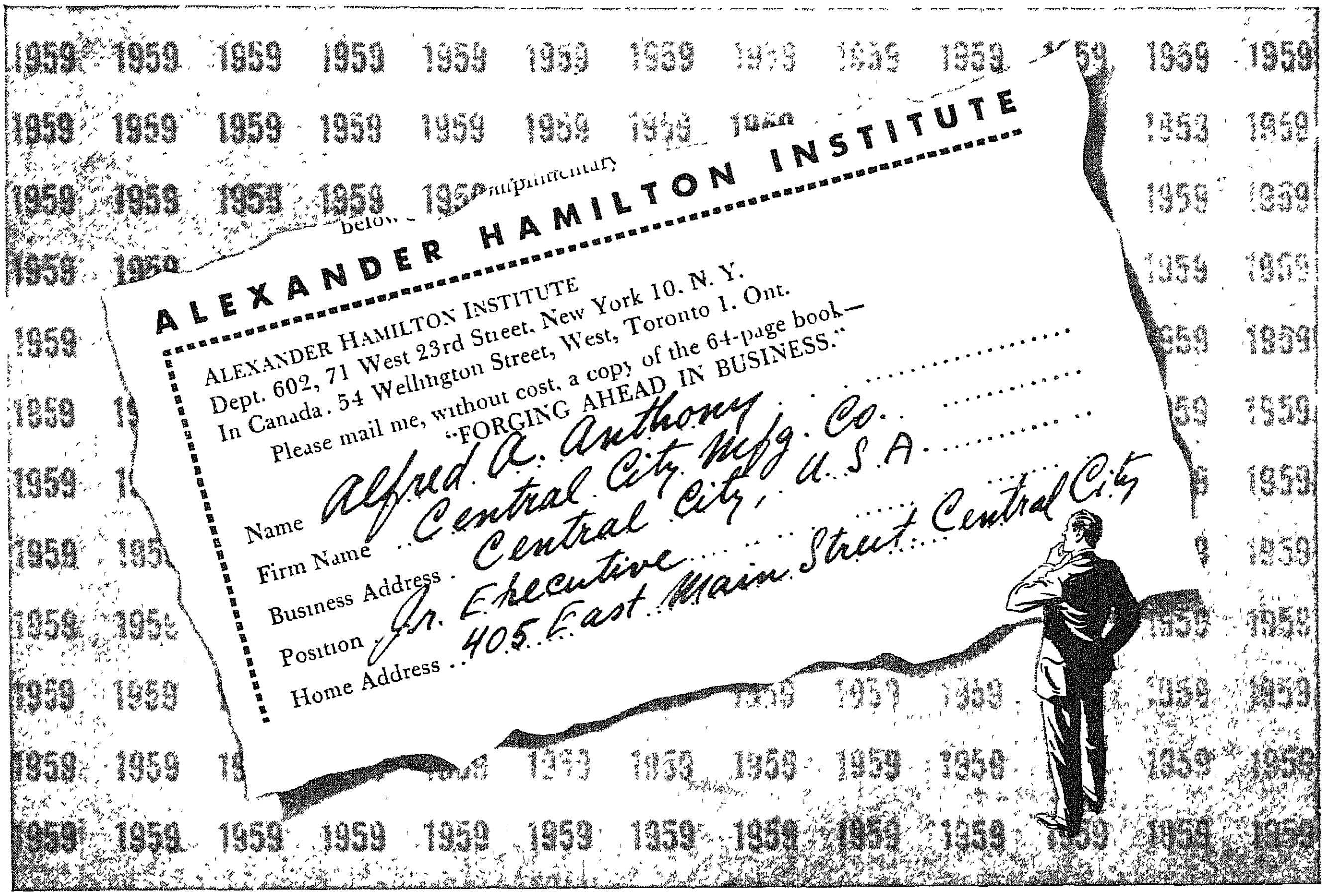
SIRS.

I should like to call your attention to the fact that the source of one of the illustrations in your January issue is not properly credited. The illustration appears at the bottom of page 37 in an article entitled "The Upper Atmosphere" It was provided by Dr. C. W. Gartlein, director of the long-term National Geographic Society–Cornell University Study of Aurora which was inaugurated in 1938. Under the heading "The Illustrations" in your January issue a photograph of the aurora made as a part of this program was credited only to Dr. Gartlein. Copyright acknowledgement to The National Geographic Society was inadvertently omitted. This note is simply to set the record straight.

FRANKLIN L. FISHER

Chief of Illustrations Division
National Geographic Magazine
Washington, D. C.

SOME MEN WILL WAIT TEN YEARS TO ANSWER THIS ADVERTISEMENT



The Years That Might Have Given Them So Much Will Pass On Forever, Casting Back a Look of Scorn

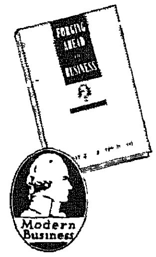
OUR files bulge with letters from men of great promise in business whose natural talents have been wasted on routine tasks.

Business, for them, has become a squirrel-cage — they work harder every year but progress no faster.

Of the thousands of men who will read this message, only the ambitious few will send in the coupon which may mean the difference between success and failure. But ten years from now, many will write letters asking for a chance to "catch up" on the years they have let slip by.

> *"Years ago I should have thought about my business future."*
>
> *"What a world of difference it would have made if I had written this letter ten years ago."*
>
> *"I put it off — just put it off."*

These are the lost and discouraged men who were content to *wait* for success; men who had no definite, well-defined program which would carry them a little closer, each day, to their chosen goal. Delay stamps its footstep on the pages of time and always leaves regret.



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For men who want to do something about where they are going to be five, ten, twenty years from now, the Institute has published a 64-page booklet titled "Forging Ahead in Business."

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50 AND 100 YEARS AGO

MARCH 1899. "The desire of the American people to have a canal at the isthmus built with their own money and operated under their own control is very natural and perfectly proper. In a recent editorial upon the canal question The London Times says. 'We are quite ready to admit that while our interests in the canal scheme are large, those of America are vital,' and what is openly and frequently acknowledged by England is tacitly admitted by every civilized people throughout the world."

"The recommendations for the increase of the navy were based upon the fact that the Spanish war has greatly multiplied the responsibilities and duties which devolve upon the navy. With the acquisition of Puerto Rico and the Philippines our vulnerable coast line has been extended a thousand miles into the Atlantic and six thousand miles into the Pacific, and a navy that was scarcely adequate to the defense of our own mainland must be greatly augmented if it is to guard the scattered possessions, the thousand and one islands, which have come into our keeping as the result of the war."

"A decade ago the imports of manufactures were more than double the exports of manufactures; now the exports of manufactured goods are 25 per cent greater than the imports of manufactured articles. In ten years exports of the articles which we are considering have increased from $78,751,433 to $182,336,503, and our magnificent trade balance is today the envy of the world."

"One of Prof. Koch's pupils, Prof. Wasserman, thinks that he has discovered a serum cure for pneumonia. Prolonged experiments with rabbits and mice have convinced him that an antitoxin is produced in the red marrow of their bones and in the marrow of human beings who have died from pneumonia."

"Drs. Lange and Melzing, of Vienna, have succeeded in taking photographs of the mucous membrane of the stomach in the living subject. A stomach tube some 60 centimeters long and with a diameter of 11 millimeters is provided with an electric light at its lower end, and at the upper end is a camera The stomach is first emptied of its contents, and after being washed is distended with air. Then 50 pictures or more can be taken in rapid succession in from ten to 15 minutes The apparatus can be turned on its axis so that all parts of the mucous membrane can be photographed. The photographs are naturally very minute, but they can, of course, be enlarged to any extent."

"A new satellite of the planet Saturn has been discovered by Prof. William H. Pickering, at the Harvard College Observatory. This satellite is three and a half times as distant from Saturn as Iapetus, the outermost satellite hitherto known. The period is about 17 months and the magnitude 15½. The satellite appears upon four plates, taken at the Arequipa Station, with the Bruce photographic telescope."

MARCH 1849. "Messrs. Beach, proprietors of the New York Sun, have negotiated for a line of Telegraph, soon to be erected, from Washington to the Sun's editorial room, and from Boston to the same center. The object of the enterprise is to get the news more correct than by the present telegraphic companies, and to get it at all times, untrammelled by any other kind of business on the wires, but that of newspaper literature. This is the greatest undertaking on record, we believe, connected with newspaper enterprise, and, what is very generous, other papers are invited to share the news on exceedingly moderate terms."

"That elegant and correct experimentalist, Faraday, has shown that zinc and platinum wires, one-eighteenth of an inch in diameter and about half an inch long, dipped into dilute sulfuric acid, so weak that it is not sensibly sour to the tongue, will evolve more electricity in one-twentieth of a minute than is given by thirty turns of a large and powerful plate electrical machine in full action, a quantity which, if passed through the head of a cat, is sufficient to kill it, as by a flash of lightning."

"We have now the largest circulation of any other paper of the same nature, in the world. The information contained in our columns is more useful than entertaining, yet to the inventor, the lover of science and the intelligent mechanic it has peculiar attractions. On our subscription list are to be seen the names of dwellers in every part of the civilized world. This shows that our columns are the source to which the eyes and hearts of our own people and the people of other nations are directed for information respecting American invention and discovery."

"Dr. Edwards, in Congress tried to abolish the law to grant Patents for Medicines, and several physicians in this State petitioned to have a law prohibiting their sale unless their composition were printed on the labels. The physicians themselves should be compelled to tell the composition of their prescriptions upon the same principle, but no such bill can pass."

"We have received a very interesting Report on the discovery of Letheon, from the pen of Dr. Edwards, of the House of Representatives Dr. Edwards was chairman of a select committee to whom was referred the memorial of Dr. Wm. T. G. Morton, of Boston, asking compensation from Congress for his discovery of the anesthetic property of sulphuric ether. Dr. Morton's claim is disputed now, it is well known, by Dr. Charles T. Jackson, of Boston, as it was also disputed by the late unfortunate Horace Wells, of Connecticut. The judgment of the committee is, that Dr. Morton is entitled to the merit of discovery, and the merit they award him accordingly."

"The steamboat Hecla while leaving the Bayou Sara, La., lately unfortunately collapsed both flues of the larboard boilers, and the steam passing entirely through the main deck which was covered with deck passengers, a great number of them were scalded, and several killed. The full number killed and wounded is not known Three were killed instantly, and a number of others were missing. Between twenty and thirty were known to be scalded, some four or five so badly that they were not expected to live. Are we never to have an end of this wholesale steamboat murder in the West?"

"From the report of 1848, submitted to Congress by the Commissioner of the Patent Office, it appears that the present population of the United States is estimated at 21,686,000."

THE COVER

The painting on the cover shows the bones and replicas of bones that are studied to trace the evolutionary relationship between reptiles and mammals (*see page 40*). In the left foreground is a cast of the skull of the mammal-like reptile *Cynognathus crateronotus* Other mammal-like reptiles are represented in the right foreground by a partly crushed skull of *Lycaenoides angusticeps* and in the center foreground by rib fragments and a left foot of *Bauria cynops*. Projecting into the picture from the right is the front half of the skeleton of the mammal-like reptile *Lycaenops ornatus*. To the left are working drawings for the study of its musculature. In the background are models of the less advanced reptiles *Stegosaurus* and *Triceratops*, and in the left background a mounted skeleton of the extinct mammal *Ursus spelaeus*. Behind the skull of *Cynognathus* is a living representative of contemporary mammals, *Mus musculus* Its present habitat is the scene of this painting, the Preparator's Laboratory of the Department of Paleontology at New York's Museum of Natural History.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
15-18	William Auerbach-Levy
21-23	Eric Schaal
28	William B. Fretter
30	Eric Mose
31	Phyllis Freier, E. J. Lofgren, E. P. Ney, Frank Oppenheimer
32	Eric Mose
33	Eric Mose
35	Ed Maker
36-37	William B. Fretter
39	Jon Brenneis
41	Eric Mose
42	John C. Germann, American Museum of Natural History
43	Eric Mose
45	Paul Kirkpatrick
47	Matthew Greene
49-51	Adolph Brotman
52-55	Lotte Jacobi
56-59	The Macmillan Company
61	Robert Kolsbun


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SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR MARCH 1949 VOLUME 180, NUMBER 3

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

MARCH 1949 VOL. 180, NO. 3

IS THE ATOMIC BOMB AN ABSOLUTE WEAPON?

P. M. S. Blackett maintains it is not, and derives therefrom some unusual conclusions.

A reply to his argument follows on page 16

by P. M. S. Blackett

THERE seem to have been many people who were so deeply impressed by the results of dropping two atomic bombs on Japan that they came to believe that the use of even a few atomic bombs would decide the course of future wars If this were true, it would indeed seem rational to single them out from all other weapons and armaments for special treatment If, on the other hand, one concludes from an analysis of the past that even a large number of atomic bombs will not by themselves decide the course of future wars between great powers, and that there exist other weapons of comparable power, then the problem of the control of atomic energy becomes part of the problem of general disarmament.

Since only two atomic bombs were used in the Second World War, and then only at a very late stage and under very special circumstances, it is by no means sufficient only to study what happened at Hiroshima and Nagasaki, on the contrary, it is essential to study the war as a whole and to attempt to assess the part played by other arms.

The combined Anglo-American bombing offensive in Germany had as its objective "The destruction and dislocation of the German military, industrial, and economic system and the undermining of the morale of the German people to the point where their capacity for armed resistance is fatally weakened." The results of this bombing offensive were analyzed by the U. S. Strategic Bombing Survey. The remarkable and unexpected result was the discovery that German total war production continued to increase till the summer of 1944 in spite of the very heavy bombing. The report comments as follows

"These figures demonstrate that German cities had a surprising resilience and extraordinary ability to recover from the effects of ruinous attacks The raids on Hamburg in July-August 1943 were among the most devastating of the war. Yet, despite the deaths of over 60,000 people, the total destruction of one third of all houses in the city and the disruption of normal processes of living, Hamburg as an economic unit was not destroyed. It never fully recovered from the bombing, but in five months it had regained 80 per cent of the former productivity, despite the fact that great areas of the city lay, and still lie, in dust and rubble. As in the case of industrial plants, when it was found much easier to destroy the buildings than the machines in them, so also it is much easier to destroy the physical structure of a city than to wipe out its economic life."

A major success of the bombing offensive was the precision attack in 1944-1945 on transportation targets and specific industrial targets such as oil installations. The Survey sums this phase up as follows.

"Not until the war in the air had been won, and the landings in the Mediterranean and France successfully accomplished, were the heavy bombers free to exploit the victory in the air and attack in full force the centers of oil production, the centers of transport and other sustaining sources of military strength within the heart of Germany. . . . The greatest single achievement of the air attack on Germany was the defeat of the German Air Force."

> EDITOR'S NOTE
>
> This discussion of the military and political implications of the atomic bomb by the Nobelist in physics for 1948 is condensed from his much-discussed book, just published in the U S with the title *Fear, War, and the Bomb* Some of the important issues raised by the British scientist are debated in this and the following article. The U. S. publisher of the book is Whittlesey House. The book, and the material taken from it here, are copyrighted by Dr Blackett.

SO MUCH has been written of the effects on Hiroshima and Nagasaki of the explosion of the two bombs that it is only necessary here to survey briefly the main facts. A plutonium bomb produces a blast wave comparable to that which would be produced by the explosion of one lump of 20,000 tons of TNT. From careful surveys of the damage to various types of buildings, it has been calculated, however, that only a little over 2,000 tons of high-explosive bombs —for example, 10-ton blockbusters— would be required to produce the same structural damage as one plutonium bomb. The reason why this figure is so

P. M. S. BLACKETT is a distinguished nuclear physicist who served as a member of the British Advisory Committee on Atomic Energy until last year.

much lower than the figure of 20,000 tons for the equivalent amount of TNT when exploded in one mass lies in the fact that such a very large explosion pulverizes nearby objects to a quite unnecessary degree, in fact, it "overhits" the central part of the target area, and so wastes a large part of the energy.

It is less easy to give a reliable equivalence for the civilian casualties produced by atomic and ordinary bombing. These depend to a very large extent on the distribution of the people at the time of the attack between open places, ordinary houses, reinforced concrete buildings or specially constructed shelters, and so will be much greater for a surprise attack on an unprepared city than for an expected attack on a prepared city. The U. S Strategic Bombing Survey, however, equates one plutonium bomb to some 2,000 tons of ordinary bombs in effect on personnel, and we will adopt this on a provisional basis, remembering that in some circumstances the figure may require considerable modification.

In order to assess the influence of atomic bombs on the course of a future war, it is necessary to estimate what changes are likely to occur by a given date in the destructiveness of the bombs, the methods of conveying the bombs to the target, and the defense. In general we will consider mainly advances that are likely to be achieved, firstly, within the next five years, that is, by 1953, and secondly within the next 10 years, that is, by 1958. For the choice of these time scales there are certain definite reasons.

It is clear that the only war in which atomic bombs are likely to be used is one in which the *main contestants* are the U. S. A. and the U. S. S. R. A period of five years from now is the latest possible date at which one could reasonably expect that the U. S. S. R. would not possess at least some atomic bombs. The period of 10 years is chosen as the latest date at which it is at all reasonable to attempt to predict the pattern of events.

THERE HAS been much discussion of the possibility of a "super bomb" probably using a nuclear reaction involving hydrogen or lithium initiated by the explosion of a plutonium or uranium-235 bomb. By this means scientists believe that an explosive power many times as great might be produced. However, this has so far not yet apparently been achieved, and its likely performance is still highly speculative. An increase in the explosive power of a bomb would yield increased results when the target is a large city, but it must be remembered that the present bombs are already unnecessarily powerful for use against many small but important targets such as a single factory or a single large ship.

Though rockets of the German V-2 type might possibly be built to carry an atomic war-head a distance of a few hundred miles, the technical problem of

making such a rocket with a range of 1,000 miles or more is very formidable. The view of the American Navy has been expressed as follows: "For these and other reasons not here touched upon, it seems a wholly reasonable and safe assumption that rockets with atomic war-heads capable of thousands of miles of range are not to be expected for at least 25 years." Certainly for ranges over 1,000 miles and probably also for ranges over 400 miles, the only vehicle for the delivery of an atomic bomb with adequate accuracy within the next 10 years will be the conventional aircraft.

Within the shorter of our two periods, that is, within the next five years, piloted bombers with a range over, say, 1,500 miles, which can be expected to be in service in large numbers, will be so inferior in speed and maneuverability as to be extremely vulnerable to contemporary fighters, and probably also to improved anti-aircraft weapons. We conclude, therefore, that repeated deep penetration of a heavily defended territory is likely to be an expensive operation. This is likely to be true both by day and by night. For the development of radar has made the night fighter nearly as efficient as the day fighter. So in this period we must conclude that effective intercontinental air war is not possible.

In the latter part of our period, that is, from 1953 to 1958, the prospects are not quite so clear. It is possible that the speed advantage of fighters will be drastically reduced. But it is also possible that new and improved defense measures will be developed. So it is likely that, certainly till 1953 and probably also till 1958, any long-range bombing campaign must be carried out in very great force.

An estimate of the scale of an atomic bomb attack which would have to be launched on a major continental power to have an important effect on its power to wage war can be made by noting the loss of territory and of industrial capacity by the Soviet Union in 1941 and 1942, and recalling that this still did not prevent her from eventually defeating the German armies and driving them from her territories. A huge number of atomic bombs would have been necessary to inflict on Russia as much damage as she actually suffered by the German invasion. In Germany some 400 atomic bombs would have been required to produce as much damage as was actually done by the Allied bombing offensive, which played by no means the decisive role in the defeat of Germany.

IT MIGHT be argued that such a calculation of the number of atomic bombs, which are to be taken as equivalent to a given weight of ordinary bombs, is inadequate, on the grounds that it does not take into account the special properties of the atomic bomb. For instance, it has often been argued that the time factor is of great importance: the argument is that atomic bombs could be dropped, say, on all the major cities of an enemy country within a few hours, and that such an attack would have an altogether greater effect than if an equivalent weight of ordinary bombing were spread out over many months.

Though it is impossible to be quite sure of the effect of such an intense but short attack, the following considerations are relevant Firstly, it is most improbable that such a widespread attack could be launched within a few hours against a well-defended country, owing to the huge air effort involved. For each atomic bomber would have to be accompanied by many other bombers, in order to have a good chance of reaching a distant target against heavy opposition.

Then again, it is not certain that it would be a sound policy to concentrate the atomic bombs in time, even if it was possible For the disadvantage to the enemy of having a large number of attacks to compete with at once would be partially, at any rate, offset by the shortening of the time during which defense measures, civilian evacuation, etc., would have to be maintained. In fact, one can see strong arguments for a deliberate policy of spreading the attacks over a considerable period of time, in order to tire out the defense and weary the population. Only if large armies were ready for an immediate invasion would a very short-duration attack be advisable.

The other common criticism of such numerical comparisons is that they neglect the psychological factor; this presumably means that the "horror" of the atomic bomb is so great that a nation's will to resist will be rapidly sapped. To this one can reply that, from the point of view of most of the individual victims, there is not much to choose between the experience of heavy ordinary bombing and atomic bombing. Selected survivors of Hamburg, Dresden or Tokyo could have provided equally poignant material for the pen of a John Hersey as the survivors of Hiroshima. Those who remember the exaggerated expectations of the effect of the British bombing offensive on German morale current in the early days of the war will be skeptical of many of the easy predictions about the effect on morale of atomic bombs. The power of human beings to "take it" is immense; a determined people will learn to stand atomic bombardment, if that is their fate.

It is clear that if Russia thought it a sound policy to drop bombs on America, she would certainly consider that it would be essential to accumulate a minimum stockpile of a few thousand before starting. Now the magnitude of the technical and industrial problems of producing bombs makes it likely that it will be many years before the Soviet Union will possess a large enough stockpile of atomic bombs to be useful against American cities. So, on this ground alone, an atomic attack on the U. S. A. by the U. S. S. R. is in the highest degree unlikely for very many years.

The next question to be answered is how the U. S. S. R. would deliver them. In the heated imagination of the enthusiasts for atomic warfare, it would only be necessary for thousands of long-range atomic bombers to take off secretly from airfields within the Soviet Union to destroy the main cities of America within a few hours. We know now that the facts are different. Even if Russia at an early stage of such an imagined war had occupied the countries of Western Europe —a far from unlikely contingency if they were allies of America—she would still have no bases from which to launch effectively such an attack

IT SEEMS improbable that Russia would plan an attack on America, except as part of a coordinated offensive with all arms, which must necessarily include invasion. A Soviet invasion of America is militarily impossible. Even if Russia controlled the whole of Europe including Great Britain, the invasion of America across the Atlantic would require an enormous amount of shipping to carry the millions-strong invasion force required, and further would be extremely easy to repulse since complete air superiority would rest with the defenders.

Even if the technical possibility of destroying American cities from European bases is much higher than we have here estimated, such destruction, not followed up by invasion and occupation, would leave America time to recuperate and rearm, bitterly determined to take eventual revenge. Further, such action would alienate world opinion and tend to solidify a grand alliance against Russia. The first Russian atomic bomb that fell on an American city would be a decisive political success for the enemies of Russia all over the world. The lesson of Pearl Harbor is clear. To strike a heavy but indecisive blow at a powerful enemy, without possessing the resources to follow it up by invasion and occupation of the homeland, is to court disaster.

Though many authoritative statements have been made discounting the possibility of "push-button war," clearly the possibility exercises a great fascination for many Americans. To be more concrete, the atomic bomb is seen in many British and American circles as the answer to the power of the Soviet armies, and the only answer that does not seem to involve large overseas military commitments. If not the atomic bomb, then "What else?"

It is necessary to consider the possibility that in the event of war breaking out, America might begin her offensive with an atomic bomb attack on Russian cities. Though, judging by the press, such a move would be widely accepted

in many American circles as a natural one, it might well be opposed by the armed services for very strong military reasons. For the military, who after all have the responsibility of carrying through such a war to a successful conclusion, cannot fail to ask "What happens next?"

It is clear that to any sustained atomic bomb attack on Russia within the next decade, there are possible Russian countermeasures, mainly with land forces, which would have the object of capturing the bases from which the atomic bombers were operating, or if this were not possible, of neutralizing them as far as possible by pushing forward her air-defense zone. Even the destruction of all the major cities of Russia would not impair the striking power of the Soviet armies until many months had elapsed If one discounts the possibility—and all our calculations have shown that we must discount it—that an initial atomic bomb attack would cause Russia to capitulate, then it is certain that such a war would be fought out in Europe on land, as were the last two World Wars.

If a war of this type did occur, acute controversy would be certain to arise between the military staff of America, on the one hand, and France and England on the other, as to the advisability of the use of Anglo-French bases for attacks on Russian cities by American atomic bombers. For, if that happened, England and France would expect to get atom-bombed—not America. And the military staffs of both European countries would certainly be made aware by their political colleagues of the difficulty of convincing the public of each country that such a role was a reasonable one for their countries to undertake

THE MOST important deduction that must inevitably be drawn from our analysis is that any future war in which America and Russia are the chief contestants—and this clearly is the only major war which needs serious consideration—would certainly not be decided by atomic bombing alone On the contrary, a long-drawn-out and bitter struggle over much of Europe and Asia, involving million-strong land armies, vast military casualties and widespread civil war, would be inevitable

Unless our analysis has been greatly in error, the danger of a Third World War in the next few years is much less than is generally thought.

Meanwhile America's stockpile of bombs will continue to grow ever bigger and bigger, and at some uncertain date Russia's will start to grow too. Responsible American statesmen will be bound to weigh very carefully the delicate question of when to begin again negotiations for the control of atomic energy, which they have just broken off. For the danger of waiting too long is great. When Rus-

A U. S. PHYSICIST'S REPLY

Challenging the Briton's strategic assumptions, he argues that a sudden air attack on military objectives would be decisive in any future war

by Louis N. Ridenour

P. M.S. BLACKETT, Nobel Laureate in physics for 1948, is a scientist of distinction and outstanding ability. He is therefore capable, as all good scientists should be, of careful and objective reasoning concerning matters that do not impinge too closely upon his faiths and implicit beliefs. Unfortunately, the subject matter of his book, *Fear, War, and the Bomb*, suggests that Blackett has allowed his pronounced political sympathies to warp his observations and his reasoning. They have apparently led him to suppress large numbers of pertinent facts, to ignore many crucial technical and political possibilities, and to depreciate the honesty and good faith of his government and of ours to an absurd degree.

Blackett attempts to establish three main theses: First, that the effectiveness of strategic bombardment has been greatly overrated, through a misinterpretation of the evidence of World War II. Second, that the atomic bomb will by no means have the impressive role in future wars which enthusiasts predict for it. Third, that the Soviet reaction to the Anglo-American proposals for atomic energy control has been entirely reasonable, for detailed reasons which we shall examine later.

Most writers who have commented on *Fear, War, and the Bomb* (which was published in England last fall) have paid attention mainly to the political matters that come under the heading of the third thesis. They have usually ignored, or even applauded, Blackett's views on strategic air power and on the atomic bomb. Since he minimizes the military usefulness of these two components of armed strength, and since both are, for the moment, substantially U. S monopolies, his assertions are a matter of sincere and immediate concern to every American.

Let us first consider the military significance of the strategic air campaign conducted in World War II Blackett discusses the area attacks upon centers of population which were carried out by the Royal Air Force; he concludes, in agreement with the findings of the U. S. Strategic Bombing Survey, that the great destruction and loss of life produced by such attacks had little direct effect upon German war production. The U. S Army Air Forces, however, devoted their attention not to such area attacks but to an attack upon target systems selected as being vital to the enemy war economy.

Blackett dwells at considerable length upon the well-established fact that the American bombings had little economic effect during all the months that preceded the summer of 1944. He gives this result its correct explanation The American air commanders, who had started the strategic air war in the belief that attacks on enemy industry could bring a quick decision, soon learned that heavy opposition from defensive fighters of the German Air Force so deranged the bombardment that its accuracy, and therefore its economic effect, was small. This difficulty being appreciated, attention was focused on destroying the GAF. It was required of the bombers only that their attacks be sufficiently annoying to draw the German fighters into battle.

BY the spring of 1944, the GAF was wrecked. Just before the Normandy invasion (the success of which hinged largely on Allied air superiority), German ventures into the air were so hazardous that a German pilot would be credited with an operational mission—a sortie in the face of the enemy—when he had merely ferried an airplane from one field in Occupied France to another. The Germans owned the land of France, but we owned the air over it. Once the GAF was finished, the accuracy, weight and effectiveness of our bombardment promptly rose, and Germany's war economy was disrupted. Nearly three quarters of the total weight of bombs dropped on Germany were dropped

sia has accumulated a stockpile of a few thousand bombs, her military strength, already very great by the size and efficiency of her armies, will be much enhanced. We have already noted that atomic bombs may prove valuable tactical weapons and even a hundred or so would be of great military value when used in conjunction with large-scale land operations, whereas such a number would bring no decisive results if used for area bombing of cities unrelated to other military operations If negotiations do not start until this situation has arisen, Russia will hold most of the cards

Let us consider what are the essential conditions for future negotiations to have a reasonable chance of success. It is undeniable that any settlement between America and Russia must be based essentially on a bargain between the two States The bargain must be one in which both sides make comparable sacrifices and reciprocally receive comparable advantages at all stages If America continues to insist, as she appears to have done in the past, on treating atomic energy in isolation, then clearly there will be no possibility of a bargain, and so none for an agreement, until Russia has drawn more nearly even with America in the field of atomic energy.

If, however, atomic energy is not again treated in isolation, if, that is, atomic bombs are considered along not only with other weapons of mass destruction but with conventional armaments and land armies as well, then it is easy to see the possibilities of an agreement acceptable to both America and Russia at a much earlier date.

On this broader basis, Russia with her strong land army has something to bargain against America's atomic bombs By taking conventional weapons and armed forces into consideration at the same time, it should not be impossible, though undeniably it would not be easy, to reach an agreement to reduce armaments generally. For instance, some kind of bargain might be struck between America and Russia, in which so many American atomic bombs and their carriers are held to be the military equivalent of so many Russian divisions

When Russia has approached more nearly to the level of industrialization of America, there will be a better chance of reaching an agreement within the single field of weapons adaptable to mass destruction. For the present it seems more hopeful to tackle the problem of general disarmament, even though this means the continued existence in the world of some limited number of atomic bombs, rather than to attempt to abolish all atomic bombs, leaving all other arms uncontrolled

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TO PROFESSOR BLACKETT

after July 1, 1944 The attacks on transportation and on the oil industry were especially effective. On March 15, 1945, the German Minister of Armament and War Production Albert Speer reported to Hitler that the total collapse of German industry was only four to eight weeks away.

Though Blackett describes all this, his conclusion from it is based upon the first phase of the air war over Germany, when the economic effects were small. He thus assumes that in any future war it will be necessary to fight for and win air superiority before substantial economic damage can be inflicted by strategic bombardment. While this may be true of the stable phase of any future war, it is almost entirely beside the point, since effective air superiority will always exist for a few days at the beginning of an air attack, and the atomic bomb is so effective that the destruction which took place in the 300 days that finished Germany can be compressed into those few initial days. Let us examine the background for this view, which differs so sharply from Blackett's.

Blackett justifies his faith in the effectiveness of air defense by an assessment of the future technical developments which he predicts for the next few years. He concludes (a) that piloted aircraft are the only proximate vehicles capable of delivering atomic bombs to strategic targets, (b) that they are of relatively short range, and will require forward bases within one or two thousand miles of the targets, and (c) that piloted defensive fighters can deal capably with attacks by piloted subsonic bombers.

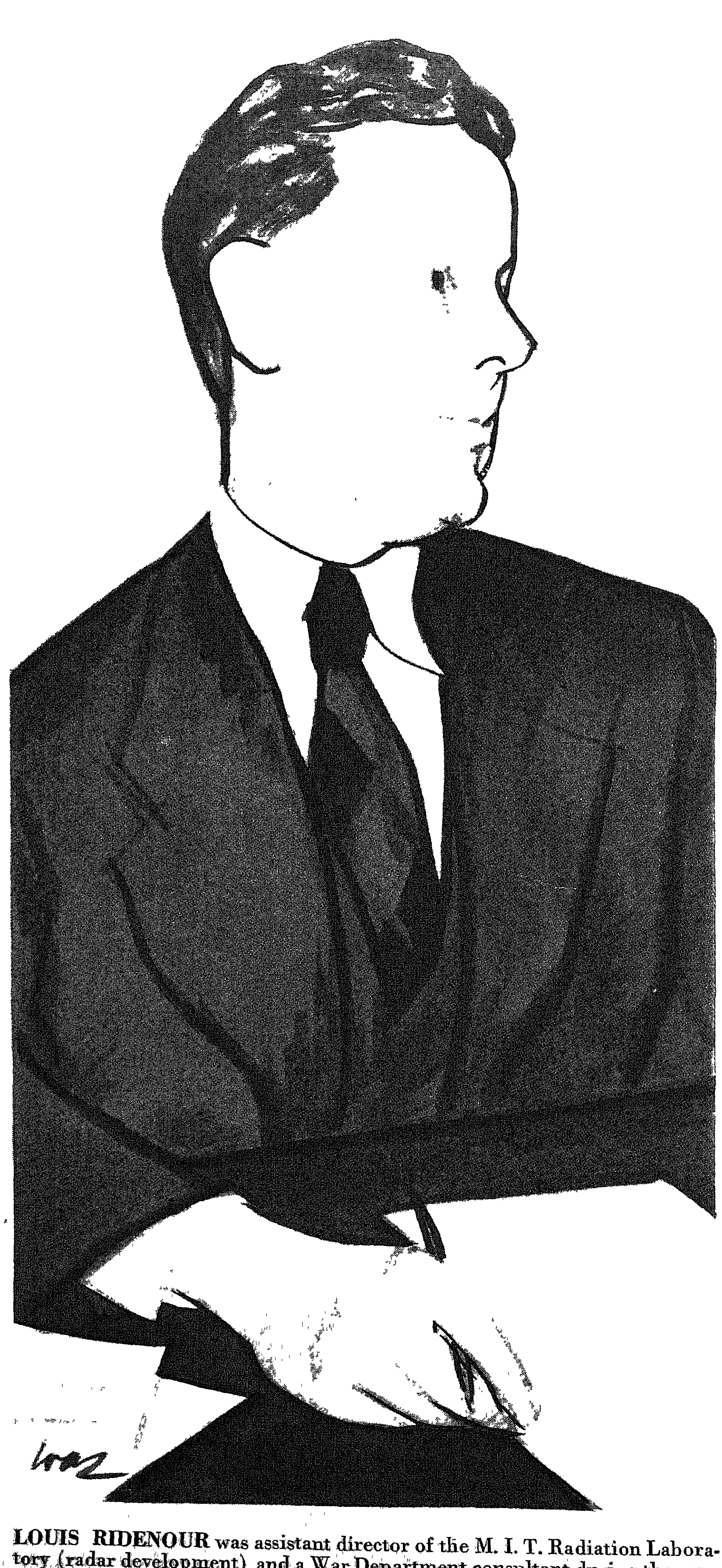
It is possible to quarrel with all but perhaps the first of these assertions. Admittedly the accurate thousand-mile guided missile will not be available until some time in the future. How far off it is, under the present circumstances of vigorous technical development, is hard to predict, Blackett chooses to put it more than 10 years away, and let us join him.

The second conclusion is wrong on the record. It is perfectly true that the B-29s of World War II needed bases within 1,500 miles of their targets However, the standard heavy bomber of the U. S. Air Force today is the formidable B-36, the actual combat range of which, on the basis of published statements, appears to be at least 3,000 miles. Also, Blackett's book was written too early to include any observations on the bomber range which can be attained by refueling in the air. The USAF has recently announced trials which indicate that this simple technique will give B-29s and B-50s substantially a global range.

Thus today's USAF bombers will deliver today's atomic bombs from here to anywhere, provided that they are not successfully intercepted. Blackett contends that they will be, and that the cost of operating unescorted long-range bombers in the face of enemy opposition will be prohibitive. This contention, too, can be debated. It rests upon an assumption that the fighter's advantage over the bomber depends only upon the fighter's edge in speed, and that this advantage is essentially independent of the actual speed at which the interception must be made. The assumption is grossly wrong, for reasons so lengthy and so technical that they are only hinted here. At high speeds, the maneuverability of a fighter is greatly reduced by the pilot's tolerance for acceleration in a turn, and by the danger of stalling out of a high-altitude turn that is too sharp. This reduced maneuverability requires that interception commence at ranges which are often greater than the maximum distance at which a fighter pilot can see a bomber, even under perfect visibility conditions. Several other major difficulties beset the problem of bomber interception at high subsonic speeds, even granting that the interceptors have a substantial speed advantage.

In any case, the point need not be labored. Granting that unescorted bombers would not be safe against air defenses in the stable phase of an air war fought in the near future, it is important to turn our attention to the conditions that would obtain during the early days of an attack. It is my contention that the entire strategic air effort could be carried out without effective opposition in those few days.

ALL defenses in all history, particularly such complicated coordinated defenses as those involved in air defense, have required time and actual combat experience to build up to maximum efficiency. Thus, for example, the German daylight air attack on England in 1940, quickly opposed and mastered by the RAF as it was, nevertheless deposited on its targets a weight of bombs which would have been decisive if they had been atomic bombs. So did the German night campaign of late 1940 and early 1941, though improving RAF defenses made the raids so costly that they were soon abandoned. I have documented this point with other examples in my chapter "There is No Defense," in the symposium *One World or None* (Whittlesey House, 1946). Blackett quotes extensively from that book, but nowhere re-



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fers to or refutes the present argument. The reason for the early failure of the defense is not far to seek. The defense must be eternally alert everywhere against any form of attack, while the offense chooses its time and place and weapons, and thus achieves initial surprise in most instances, and local superiority in all.

So long as the initial unmolested air attack had to be delivered in terms of old-fashioned "high explosives" and incendiaries, it could achieve a significant local success (as at Pearl Harbor), but could not be decisive. With atomic bombs, all this is changed. Blackett quotes, and agrees with, current estimates that one bombing aircraft carrying one atomic bomb is equivalent in terms of practical destructive power to between 50 and 250 heavy bombers with old-fashioned bombs Unlike most other experts, he asks us to take comfort from the circumstance that the number is not bigger. The German economy was destroyed completely, according to the argument which Blackett himself makes, in the 300 days from July, 1944, to April, 1945, since there had been no significant economic effect earlier, we can draw no other conclusion. This means that the bomber forces of World War II could have achieved the same result in perhaps two days if they had used atomic bombs.

What targets would be attacked in those two days? Blackett assumes that we would desire to destroy the cities of the enemy. He even depreciates the value of strategic air attack on the grounds that the Russians might, in another war, occupy the whole of Europe, he argues that we would not, and dare not, bomb the cities of our friends.

In terms of capabilities, we could surely use our brief initial air superiority to lay waste all the major cities of an enemy. In terms of military realities, we would almost certainly not do so Blackett himself has shown that attacks on cities had small result in World War II, while attacks on specific industrial target systems brought the Germans to collapse. This being so, even though there is some evidence that an atomic-bomb attack on civilian populations might be much more effective than were such attacks with old-time "high explosives," our decision would undoubtedly be to launch our strategic attack against carefully chosen points in the fabric of the enemy's industry. There would be two cogent reasons for making this choice. 1) the proved military value of such attacks; 2) the fact that the tremendous loss of irrelevant lives in city bombing is repugnant to any proper conscience.

Since industries are not usually *in* cities but on the periphery, they could be attacked even though they were in occupied friendly countries. In the absence of effective opposition during the first apocalyptic days, the bombing would be accurate, and there need be

little indiscriminate killing of people living in the nearby cities It is even possible that the raids could be announced beforehand, as Major General Curtis E. LeMay announced his targets in a late phase of the Pacific air war, without such an announcement aiding the initial air defense in any significant way. This, however, is speculation, and the risk might be regarded as too great to take.

IN any case, another war is likely to involve, early in the conflict, the destruction by one power of certain vital economic target systems of the other. The aircraft producing this destruction would carry atomic bombs, one of them would be more terrible than an entire old-fashioned combat wing, while half a dozen would be equivalent to an old-time thousand-plane raid The weapons could be so used that the lingering radioactivity spewed over the factories and the installations that were hit would deny their use for months or years

Other aims, no doubt, would be involved in such a conflict. There is no quarrel on that point, indeed, our present pattern of military expenditure suggests that we put no complete reliance on strategic bombing with atomic weapons But to say, as Blackett does, that long-range bombers cannot be decisive, and that the atomic bomb changes nothing, is to assert that the war economy of a nation is of no value to that nation in a war. Reduced to these basic terms, Blackett's contentions are preposterous.

The view here presented is not a pleasant one to take. Yet in today's nervous and hostile world, we are committed to a national policy of maintaining our armed strength The long-range striking arm of that military strength is the strategic bomber, with its atomic weapons. Blackett does the Western world no service when he affects to deny the usefulness of strategic bombardment

It may be that the very curious nature and the obvious bias of Blackett's political remarks will warn the reader that the military considerations he advances are also suspect. In the latter part of the book, Blackett presents the following astonishing arguments: First, that the dropping of two atomic bombs on Japan in August, 1944, was the first move in the cold war, designed to forestall a Russian offensive in the Far East. Second, that the Baruch proposals for the international control of atomic energy, based with devilish ingenuity on the altruistic program of a group of high-minded men, were another move in the same game, and were designed to put the Soviet Union at a moral disadvantage Third, that the scheme for control contained a thinly disguised attempt to deprive the Russians of an unparalleled opportunity to raise the living standards of their masses by the peaceful exploitation of atomic power.

The usual reason given in the U. S. for the timing of the use of the first atomic bombs is that the bombs were not ready earlier. The reason advanced to explain the nature of their use is that a dramatic demonstration of the bomb's power was felt to be necessary to convince the enemy of its effectiveness, as promptly as could be done The whole affair is said to have been calculated to result in the speediest termination of the war, and the smallest loss of American and Japanese lives. We have all this on the solemn public testimony of the men responsible for the decisions. Blackett brushes it aside, he does not even summarize these arguments as meriting serious attention The closest that he comes to them is in what he calls the "Roman holiday" theory, that, having spent two billion public dollars on a weapon, the American people were entitled to the bloodiest possible demonstration of its effectiveness. He states that many Americans espouse this view, I know one who does not.

ON Blackett's assumption that we dropped the bombs to prevent the Russian grab in Manchuria (he does not call it that), how did we succeed? Russia took Manchuria, a proceeding that we could not have prevented even though we wished to do so Consider also how we held back at Berlin and Prague until the Russians got there, in accordance with our agreements that their troops could enter these cities first.

The second of Blackett's political assertions that I have mentioned above is best dealt with by stating it in his own words. He says, comparing the Baruch and the Gromyko proposals for atomic energy control, "It is hardly likely that either the American or the Russian Governments had serious expectations that their proposals for control would be accepted by the other As has already been emphasized, the American proposals constituted a very shrewd move in the diplomatic cold war, promising concrete advantages in the event either of their acceptance or their rejection American diplomacy had maneuvered Russia into the disadvantageous position of having to reject a speciously fair offer."

Nothing I can say will make this assertion seem more absurd than it shows itself to be. Quite apart from the obvious sincerity with which the U. S. approached this problem, it is more than I can manage to believe that our democratically cumbersome and bumbling foreign policy can have reached the heights of guile suggested by Blackett.

As to his argument concerning the industrial applications of atomic energy, and Russia's need for atomic power, one can only say that this is nonsense. To be the great industrial nation that she hopes to become, Russia needs power, indisputably; but the sources of it now lie ready to her hand. Her coal reserves are the second largest in the world; her potential of water power is the largest; by her own assertion her petroleum resources are larger than those of any other country. With this great wealth in the conventional power sources, Russia should be less dependent on atomic power than any other country.

Further, the development of power from conventional sources is a straightforward business which is well understood by engineers. We are only in the faltering beginnings of the engineering of atomic power. How shall we deal with the great intensity of lethal radiation? What structural materials best resist it without change and failure? How do we transfer heat efficiently in a structure the design of which is dominated by the necessities of its service as a reactor? How shall we dispose of the intensely radioactive wastes? Can we make a reactor that will both deliver useful power and "breed" new atomic fuel? How shall we guard against explosions? In view of these and other vital questions, practical atomic power is too far off to be a factor of significance in past or current policy.

ALTOGETHER, Blackett's book appears to be an elaborate and lengthy defense of a set of fixed ideas held at the start. J B. S. Haldane, one of Blackett's colleagues in the British left, has said of him: "He has a mind which seems to be much happier with real things, which he can count and measure, than with the more abstract forms. . . What is more, he finds the things he is looking for." Haldane's remark, made in an altogether different context, is particularly apt as a description of the way in which the ideas and arguments of Blackett's book must have been arrived at.

His ideas coincide remarkably with the standard Russian views. He belittles the atomic bomb—which Russia has not got, but wants. He depreciates strategic air power—which is the only arm we have that can strike a blow at Russia (she does not fear our armies, surely, and she has no vital seaborne commerce to defend). He indulges in the most remarkable gymnastics of rationalization to convict us of chicanery in our external atomic policy—despite a U. S. proposal the generosity of which is unparalleled in the history of diplomacy. Blackett, and the Russians too, consistently refer to the limited world government which so many Americans desire as a "world hegemony" dominated by the U. S.

Blackett's argument carries its own antidote. The excesses and the absurdities of the political views he urges are so clearly the result of bias, and so clearly dominated by pro-Soviet prejudice, that the whole work is suspect, and will appear so even to the least discerning.

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THE ALARM REACTION

Investigators at the University of Montreal have observed physiological changes in animals subjected to stress. Do similar changes take place in the harassed human animal?

by P. C. Constantinides and Niall Carey

IN BIOLOGY and medicine it is becoming increasingly difficult to see the forest for the trees. The specialization of modern research leads into ever-narrowing paths. One man spends an entire lifetime studying a single hormone, another an enzyme, another the circulation of the kidneys. Year by year the data pile up; yet in some respects this vast accumulation of facts is leading us no nearer to an understanding of the living organism as a whole. Biologists have pushed so far into their individual tunnels of exploration, and there are so many tunnels, that the relation of one finding to another may elude discovery for years. Obviously we have reached a point where it is highly desirable to widen the view, to conduct researches in breadth as well as in depth.

At the Institute of Experimental Medicine and Surgery, the University of Montreal, Dr. Hans Selye and his team of biologists have been pursuing such an investigation for more than a decade, with stimulating results. They have been studying the generalized reactions of a whole animal to the stresses produced by its environment. A living organism consists of salts, enzymes, hormones, energy and a host of other elements, each of which may react in a specific way to some assault from outside; but the response of the organism as a whole is more than the sum of all these reactions. Life, and even death, is a chain reaction, and it is this linked process that Selye's group has been examining.

The particular focus of the investigation is the adaptation of animals to various types of severe or prolonged injury that affect large sections of the body. From this work has come the discovery that the animal organism possesses a general defense mechanism which it automatically mobilizes against any damage, whatever the cause. The principal agent of the mechanism is the endocrine system. As the officers of the defense, the hormones call upon various organs of the body for extraordinary efforts. If the stress becomes too great, the animal is destroyed by its own defenses, for ultimately the strain is conveyed to the heart and the circulatory system. Thus the research leads directly to a study of high blood pressure, hardening of the arteries and heart failure—the principal causes of death among human beings today.

Selye started this work some 12 years ago as the result of certain unexpected findings during some experiments on rats. He was investigating their specific responses to various drugs, poisons and gland extracts. He injected heavy doses, sufficient to kill the rats in a day or two, and made a careful autopsy of every animal. He was surprised to find that every substance he injected produced exactly the same result in three of the animals' organs: 1) the adrenal glands swelled to twice their usual size and changed in color from yellow to brown; 2) the thymus withered away; and 3) the stomach lining was spotted with bleeding ulcers. The puzzling fact was that these reactions were caused by such widely diverse substances as atropine, strychnine, formalin, crude pituitary extracts—all entirely different in chemical structure and mechanism of action. The only factor that the many agents had in common was that all were injected in quantities dangerous to life. Selye reasoned that the responses he observed must represent a nonspecific reaction to general damage as such, regardless of the specific agent that caused the damage.

If this were true, other types of acute stress ought to provoke the same response. Selye tested this assumption by subjecting animals for some hours to cold, to excessive muscular exercise, to fasting, to emotional excitement and to numerous other kinds of injuries. Sure enough, all these nonchemical types of stress elicited in the animals the same unmistakable "alarm reaction" (AR), as he called it.

It was soon discovered that certain characteristic chemical changes in the tissues and body fluids always accompanied the AR. Among the first to be studied were the sugar and the chloride ions of the blood. During the first few hours of exposure to stress, it developed, both of these fall to subnormal concentrations. After a few more hours, they rise above normal values. The two periods are now known respectively as the "shock phase" and the "counter-shock phase" of the AR.

AS a result of a great amount of work, done mostly in Canada and the U. S., we know considerably more about the AR today. Its anatomical and biochemical aspects have been studied in many other species besides the rat. There is no doubt that it represents a general defense reaction against sudden stress in many higher vertebrates, including man.

The most dramatic changes during the AR occur in the adrenal glands. The two adrenals of an average human adult weigh together not more than 10 grams—about one 7,000th of the total body weight. But they are extremely important organs; if they are destroyed, as in Addison's disease, death is inevitable. With the exception of the brain centers for breathing and vascular tonus, there is no other equally small part of the body whose destruction or removal results in so quick a death. You can remove both legs, two thirds of the liver or a whole kidney and life will not be endangered, but if you remove an animal's adrenals, it loses its resistance to the slightest damage and dies within a few days. Obviously, then, the adrenals hold a key position as regulators of vital functions.

The gland has a capsule, or cortex, enclosing a marrow, or medulla. It has been known since the beginning of the century that the medulla produces adrenalin, a hormone that constricts blood vessels, raises the blood pressure, and mobilizes sugar from the liver in emergency situations. The function of the cortex—the only portion that enlarges in the alarm reaction—is a more recent discovery. It is now known that the cortex produces hormones indispensable to life, storing them in fat droplets, or lipids, which give the cortex its yellow color. All of these hormones are steroids, that is, fat-soluble compounds with the same basic chemical structure as the sex hormones, the cancer-producing hydrocarbons, the active ingredient of digitalis and certain other substances. At least 20 adrenal cortex hormones are known.

These are the messengers that marshal the alarm reaction. During the first hours of the AR, the hormones in their

lipid vehicles are rapidly discharged from the adrenal cortex into the bloodstream and race to the tissues of the body. There they perform their various functions, of which two are definitely known. 1) They keep the composition of the fluid cell environment constant, mainly by retaining salts, particularly sodium, in the solution between the cells. The most important salt-retaining hormone is desoxycorticosterone, more commonly known as DCA. 2) They promptly build up sugar, a ready energy donor, from other materials, particularly proteins.

How important these two functions are can easily be judged from the fact that animals whose adrenals are removed die with their blood almost drained of salt and sugar. On the other hand, the injection of salt-retaining and sugar-forming adrenal hormones can prolong the life of such animals considerably, it also raises their resistance to otherwise fatal stress.

Yet the adrenal itself does not act independently It is merely an executive of higher coordinating centers, from which it receives orders as to when to act, how much to act and what hormones to discharge The adrenal cortex, like almost all other endocrine glands, is under the direct command of the anterior part of the pituitary gland—the "leader of the endocrine orchestra" If the pituitary is removed, the adrenal cortex shrinks and becomes inactive It can regain its normal size and function only if a new pituitary gland is transplanted into the animal or if pituitary extracts (*i.e.*, hormones) are injected.

Fundamentally, then, the AR is controlled by the pituitary. Remove this gland, and no AR can occur, when the animal is placed under stress there is no activation of the adrenals, no thymus destruction, none of the other typical AR changes Yet the pituitary cannot act alone an animal whose pituitary is left intact but whose adrenals are removed shows no AR in response to stress.

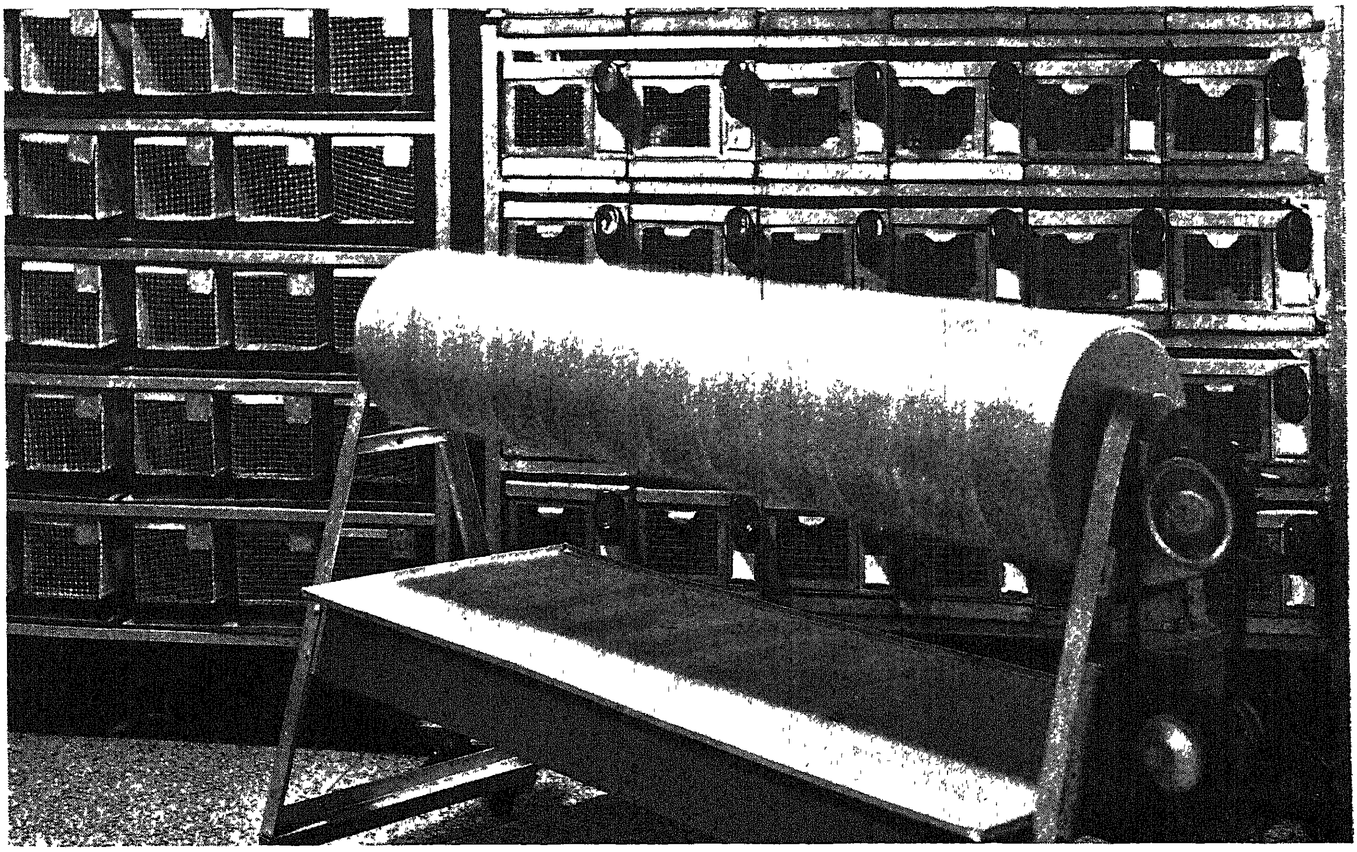
Thus a long series of experiments clearly outlined the AR mechanism. Acute stress acts on the anterior pituitary through some unknown pathway, the pituitary replies by mobilizing the adrenals, which discharge their hormones, which in turn destroy the thymus and effect most of the other changes. This process has been found to be set in train by hundreds of damaging agents. There are, however, a few interesting exceptions Certain stress agents can destroy the thymus directly in animals whose adrenals have been removed. A significant fact is that all these "unusual" agents have something to do with cancer.

AFTER the alarm reaction was established, the next major step in the experiments was an investigation of animals' long-range responses to stress. What would happen if the organism were exposed to continuous, prolonged stress of an intensity below the lethal level, a stress strong enough to strain the defenses almost to the limit, yet not sufficiently overwhelming to silence all defense at once?

Animals were subjected to sublethal daily stress with the same agents for several weeks instead of a few days. During the first few days, the organism responded with the usual AR. It showed the typical organic and chemical changes, growth and sex functions ceased, and all the signs of an intense tissue breakdown were present.

As the stress continued unabated, the animals that survived the AR began to recover The adrenals started to refill their empty stores with lipids and reverted to normal size; the thymus began to regain its mass, and such substances as sugar and chlorides in the blood rose to normal or even higher levels. At the height of that state the organism had in some way accomplished an adaptation to the continuing stress. Its organs and their functions were apparently returning to normal. In some instances it was difficult to distinguish such animals from control animals not under stress. This stage, lasting from a few weeks to a month or more, was called the "stage of resistance."

It should be noted, however, that resistance increased only against the one type of stress employed from the begin-



RATS ARE EXERCISED in a motor-driven drum at the University of Montreal's Institute of Experimental Medicine and Surgery. When they are regularly subjected to this kind of stress, the rats develop the familiar symptoms discussed in this article: enlarged and discolored adrenals, a wasted thymus and ulcers of stomach.

ning It, in the middle of this recovery period, the stress against which adaptation developed was replaced by a different one, the animals succumbed immediately. Quantitative experiments with graded amounts of stress showed that while the animal's specific resistance to the initial agent increased, its resistance to any other stress decreased

The adaptation to the original stress was not permanent. As the strain continued after the recovery period, the animals became progressively weaker, the adrenals enlarged again and discharged their lipids, the thymus lost the mass it had recovered; sugar and chlorides fell to dangerous levels; after a few weeks all defenses collapsed and life ceased. This last "stage of exhaustion" was similar to the initial alarm reaction. The end was like the beginning.

Thus the struggle of life against stress was found to consist in three successive acts, all aiming at a balance which was not quite attained during the AR, was achieved during the stage of resistance but was lost again during the stage of exhaustion. Evidently the war of the organism against damage was waged at the expense of a finite capital of "adaptation energy." The whole battle was named the "general adaptation syndrome" (GAS).

THE establishment of the GAS opened a number of fascinating fundamental problems. Life as a whole could be regarded as a GAS that ends when adaptation energy runs out. More immediately, the phenomenon suggested some studies of great medical interest.

Some types of stress are so severe that an animal can develop resistance for only a very short period; others permit a prolonged adaptation before the animal becomes exhausted. Animals can adapt themselves to cold, for example, for periods as long as two or three months. And such animals presented quite unexpected changes The arteries were enormously thickened and their bore was narrowed almost to obliteration in numerous districts of the body; the heart was abnormally large and filled with nodules very like those appearing in human rheumatic disease, the kidneys were largely destroyed through hardening and closing of their vessels—as in human nephrosclerosis—and the blood pressure rose more than 50 per cent. In other words, long-lasting stress had produced in these animals hypertension and cardiovascular disease.

This was a finding of the highest importance in experimental medicine. It suggested that these diseases might be caused by the pituitary-adrenal mechanism, perhaps by the excessive production of their hormones. If one could produce the changes found in these animals by loading the organism with large quantities of pituitary and adrenal hormones, then at least some forms of degenerative diseases would appear to be the consequences of "over-adaptation," *i e*, the defense mechanism that an animal develops during the stage of prolonged resistance to stress.

The experiment was made. A number of animals were dosed with large amounts of these hormones. Extracts would not do for this purpose, for one can never be sure how much hormone they contain or that they include everything produced by the gland in the natural state. Fortunately the previously mentioned adrenal hormone desoxycorticosterone, or DCA, was available in pure, crystalline form. Because chemists have not succeeded in synthesizing any pituitary hormones, it was decided to use the whole anterior lobe of this gland, powdered and suspended in water In laboratory terms the product, "lyophilized anterior pituitary," is referred to as LAP Continuous injections of large amounts of DCA or LAP are equivalent to the prolonged and excessive secretion of hormones by the adrenal or the pituitary, respectively.

The results were remarkable. In three weeks the animals that were injected with DCA developed severe hypertension and hardening of the kidneys. Those treated with LAP showed a strikingly similar picture, though after a somewhat longer interval.

In medical research one can never lose sight of the ultimate objective, namely, the cure of patients. The investigator first devotes every effort to reproducing a disease in animals, and when he has succeeded he turns to the endeavor to destroy that disease. In searching for ways to combat the diseases produced by too much hormone production, one of the most obvious targets would be to try to neutralize the hormonal excess, in other words, to find a chemical antidote. Logical as it seems at first sight, this is too complicated a task at present. In the first place, we do not yet know the chemical mechanism of the hormones' action. Secondly, we must not forget that the organism needs those hormones, even if by overproducing them it poisons itself with its own defense substances.

A more practicable approach was suggested by experience in the treatment of other endocrine diseases. Some of these diseases can be alleviated by control of the diet. A case in point is diabetes, in which the basic trouble is a hormone deficiency. In moderate cases diabetes can be completely controlled by a diet low in sugar.

It was conceivable that the experimental hypertension produced in animals by overdoses of hormones or by stress might flourish on some diets and be suppressed by others. The animals were therefore subjected to a great variety of diets, a process which had to be pursued by trial and error because there was little indication as to what diets might be helpful

FROM the many tests, two facts emerged clearly. One was that experimental hypertension produced by DCA was markedly affected by salt in the diet. A high salt intake increased both the frequency and the intensity of the pathological changes caused by that hormone. Contrariwise, when the animal was fed a salt-free diet, it was immune to hypertension, even when considerable amounts of DCA were injected. The second finding was that hypertension caused by stress or LAP was not affected by salt at all but was influenced by protein in the diet. A low-protein diet afforded considerable protection to the animals, while a high-protein intake aggravated the damage.

Thus sodium favored the adrenal hormones, and proteins favored stress or the pituitary hormones in their injurious effect on blood vessels and blood pressure. The why and wherefore of these results is still unknown. It may be that DCA cannot act without the simultaneous presence of sodium. Perhaps the pituitary manufactures adrenal-stimulating hormones from food proteins. Research on these questions is now going on. One of the present objectives is to find out whether it is the total quantity of proteins that counts or a protein constituent, *i e.*, an amino acid.

In any event, these experiments tend to strengthen the case for the widely held belief that some forms of human cardiovascular disease are due to hormonal derangements. Medical experience has taught doctors that patients with high blood pressure fare best on a low-sodium, low-protein diet. This is exactly what the animals needed to withstand the destruction of their blood vessels by prolonged stress or by hormones.

The research of Selye's group yielded another key fact, namely, that in this whole general process the kidneys are somehow deeply involved. They are early victims of damage in the resistance phase of the GAS or during the inundation of the body with pituitary and adrenal hormones But they also seem to be something more than passive targets. A great deal of work since the turn of the century has shown that the kidney itself can become the active cause of the most malignant hypertension. There is considerable evidence now that under certain abnormal conditions parts of the kidney tissue may stop their normal function, which consists in filtering the blood and producing urine, and start producing hormones that raise blood pressure. In the rat, this was beautifully demonstrated by what is now known as the "endocrine kidney" of Selye. By a surgical operation that interferes with the blood supply of one kidney, the whole

organ is transformed into an endocrine gland, and in a few days the blood pressure rises to fatal levels. It is a particular feature of the endocrine kidney technique that only one kidney is transformed into a gland while the other gets all the damage

Correlation of the evidence derived from all the numerous experiments on the GAS has led Dr Selye to formulate the following current hypothesis. Long-lasting stress provokes an excessive production of adrenal-stimulating hormone in the anterior pituitary, this forces the adrenal cortex to an intensive discharge of DCA-like hormones which, among other things, affect the kidney in such a way as to release hypertensive substances.

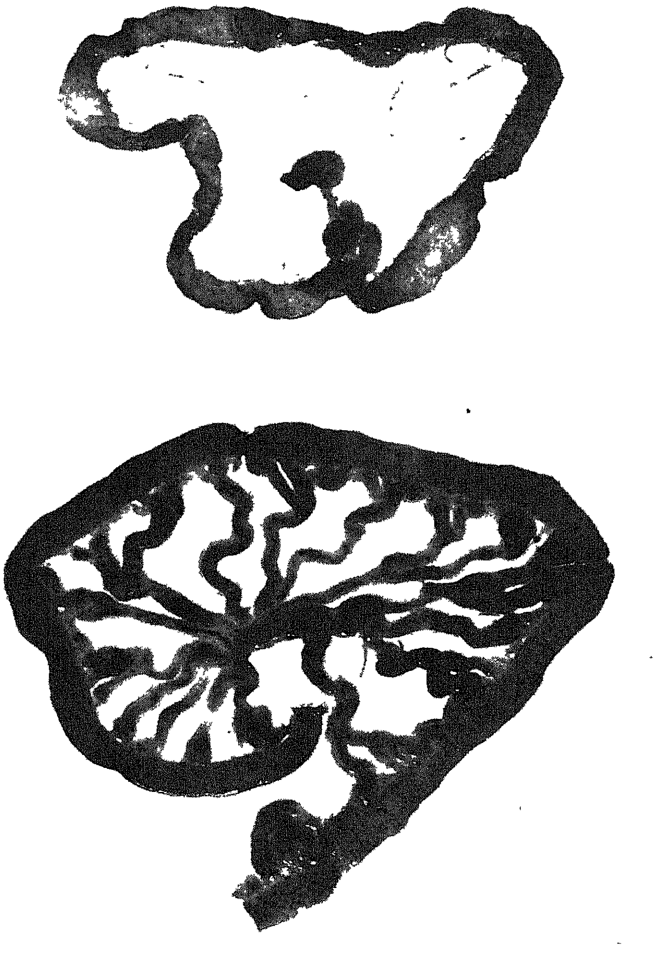
IN a sense the research is only beginning. Its implications are tremendous. In the GAS we seem to see the merest outlines of a great biological chain reaction which can be set off by almost any stress and which may frequently lead to the suicide of the organism. Some of the links in this chain are still missing, but its essential structure has been amply confirmed As a result, large-scale research in this field is now starting in many laboratories

Should further research prove that chronic stress can produce the same disorders in man as in animals, it would appear that the most frequent and fatal diseases of today are due to the "wear and tear" of modern life One might question whether stress is peculiarly characteristic of our sheltered civilization, with all its comforts and amenities Yet these very protections—modern labor-saving devices, clothing, heating—have rendered us all the more vulnerable and sensitive to the slightest stress. What was a mild stress to our forebears now frequently represents a minor crisis. Moreover, the frustrations and repressions arising from emotional conflicts in the modern world, economic and political insecurity, the drudgery associated with many modern occupations—all these represent stresses as formidable as the most severe physical injury. We live under a constant strain; we are losing our ability to relax, we seek fresh forms of physical or mental stimulation.

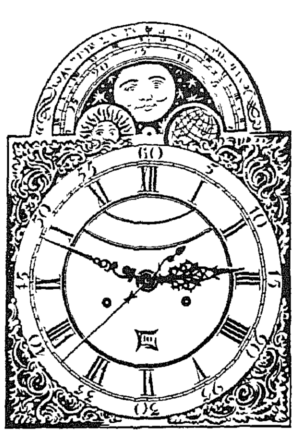
Thus it would not be surprising to find that much of our organic disease derives from psychological trauma, with the general adaptation syndrome as the bridge that links one to the other. If this be true, medicine may eventually find a cure for the consequences of stress; but prevention of the basic causes will remain a task that lies beyond its reach.

P. C. Constantinides and Niall Carey are research assistants in the Institute of Experimental Medicine and Surgery at the University of Montreal.

ADRENALS of a normal rat and of a rat that has been subjected to stress are compared. The gland of the normal rat (*top*) is a tiny organ with a yellowish color which is due to droplets of hormone-bearing lipids. After stress the gland becomes greatly enlarged and its color is changed to brown (*bottom*).



BLOOD VESSELS supplying a segment of rat intestine are similarly compared. The intestine of a normal rat (*top*) is supplied by fine vessels. The vessels of a rat subjected to stress (*bottom*) are enormously thickened. The sclerotic vessels contribute to high blood pressure and death of the organism.



SCIENCE AND THE

Atomic Energy

HOW LARGE is the U. S. stockpile of atomic bombs? The question was raised last month by Senator Brien McMahon of Connecticut, chairman of the Joint Congressional Committee on Atomic Energy, who suggested that the Atomic Energy Commission prepare a report on the advisability of making the information public. He was rebuffed—by fellow members of his Committee, by the President at a press conference and by U. S. delegates to the United Nations, who notified the Security Council during a debate on armaments that there would be no release of atomic arms data.

That the stock of atomic bomb materials is now substantial was made fairly clear in the recently released semiannual report of the AEC to Congress U. S. production of uranium 235 and plutonium, which fell off after the war, passed the wartime rate late in 1948 and continues to rise. The improved bombs tested at Eniwetok last spring have been or will soon be placed in production. The output of both bombs and fissionable materials will be further increased by the addition of new plants, to the construction of which is allocated 40 per cent of the $792 million budget requested by the AEC for the coming year.

The AEC report, the most comprehensive yet issued, ranges in detail over a huge program of activities—and problems. Two of the three plants at Oak Ridge, it reveals, no longer produce U-235. The plant formerly used for the electromagnetic separation of U-235 is now employed in the purification of tracer isotopes. The thermal diffusion unit is being dismantled. Improvements in the gaseous diffusion plant have at least partly made up the loss of U-235 output from the other establishments, and a large addition to the gaseous diffusion plant is to be completed by 1951.

Plutonium production at Hanford has been raised above the wartime level through extensive repairs to the chain-reacting piles, which had been close to breakdown. The report adds that nuclear piles may eventually become so poisoned by radioactivity that they will have to be shut down permanently. Consequently the several new plutonium piles to be built at Hanford this year may replace rather than supplement the original Hanford reactors.

Meanwhile the efficiency of the existing nuclear fuel plants has been improved. Savings of 15 to 21 per cent have been effected in several processes, such as the preparation of uranium oxide and the refining of metallic uranium.

In regard to personnel problems, the AEC admits that "progress has not been satisfactory." To speed up the security clearance of employees the Commission recently issued a set of standard eligibility criteria. These have added some new questions, such as whether an employee has close relatives in "Iron Curtain" countries They also require a form of clearance, termed "security approval," of contractors' employees whether or not they have access to secret material. In spite of the various steps taken, the clearance procedure has not been accelerated to the point where the AEC can tackle the long-standing problem of granting hearings to applicants for positions who fail to obtain clearance. At present only those already on the AEC payroll have the right to a hearing.

In its review of scientific advances the Commission reports that Los Alamos physicists have liquefied helium 3, the rare light isotope of that element. The temperature at which helium 3 liquefies is 3.2 degrees absolute (—269.8 degrees Centigrade), which is nine tenths of a degree below the boiling point of ordinary liquid helium. Not enough helium 3 has yet been accumulated to determine whether it behaves as a superfluid, like helium 4, or as a normal fluid, as present physical theory predicts

Among other discoveries is a new type of chemical reaction which may ultimately be of great importance. Workers in several laboratories have found that when a salt such as potassium chloride is irradiated with neutrons in a pile to transmute chlorine 35 into sulfur 35, the product is not potassium sulfide, as expected, but potassium sulfate. Nothing like this had been observed before. In some unexplained way the energy developed in the pile oxidizes the sulfur from a sulfide to a sulfate. Since oxidation is fundamental to many processes in chemistry, this new type of oxidation reaction may have important applications.

The AEC will soon build a large laboratory somewhere in the West to house the plant to be built for the Westinghouse Electric Corporation to study the application of atomic power to ship propulsion. It also plans to construct a new type of nuclear reactor which will operate at the highest radiation intensities yet attempted. This reactor will test materials for still "hotter" piles to come. The plans were announced by Robert F. Bacher, physicist member of the Commission, before the American Academy of Arts and Sciences Bacher also described in more detail the previously announced experimental power piles to be built at the AEC's Argonne and Knolls establishments. Both will be "breeders" —reactors that create more nuclear fuel than they consume—and they will utilize liquid metal to carry heat from the atomic ovens to the power plant proper The Argonne pile will use fast neutrons, the Knolls pile, the first of its kind, will operate on neutrons of intermediate energy. In addition, the AEC is working on the design of a low-power research pile simple and inexpensive enough for construction at a number of laboratories now without pile facilities

In June the Commission will publish a detailed report on the effects of atomic bombs. The report is being prepared by a large staff of contributors under the editorship of Norris Bradbury, director of Los Alamos, and Joseph O. Hirschfelder of the University of Wisconsin. It will cover blast, heat and radiation effects of atomic explosions over land and in water, and will discuss the problem of civil defense against atomic attack.

Soviet Uranium

ALTHOUGH the U S. S R. has no known uranium deposits as rich as those in the Canadian Arctic, the Belgian Congo or Czechoslovakia, low-grade ores are plentiful enough to support a Soviet atomic power industry, according to a survey of Russian geological literature by D. B. Shimkin of the Harvard University Russian Research Center. He reports in *Science* that promising uranium-bearing deposits exist in three areas of the U. S. S. R The largest, in the Fergana Valley east of the Caspian Sea, have been mined on a commercial scale for 41 years. They resemble, in composition as well as in size, the carnotites of the western U. S. The other deposits, of a different type, are in Siberia northeast of Lake Baikal, and in the Ukraine.

The Fergana area, Shimkin points out, is well suited to atomic industry. The deposits are within 250 miles of a large hydroelectric plant at Tashkent. Transportation, labor supply and climate are favorable, and the area is distant from Russia's western frontier. It may there-

CITIZEN

fore be one of the chief centers of current Soviet atomic energy efforts.

Man-Made Mesons

MESONS, the puzzling particles found in the debris of atomic nuclei shattered by cosmic rays (*see page 28*), were first produced artificially a year ago by bombardment of atoms with 400 million-volt alpha particles. They have now been created by similar bombardments with X-rays and protons. The University of California Radiation Laboratory announces that mesons were made by a beam of 300 million-volt X-rays from its new synchrotron and by 350 million-volt protons from its 184-inch cyclotron.

The California synchrotron was placed in operation January 17. Invented independently by E. M. McMillan of the Radiation Laboratory and the Russian V. Veksler, the synchrotron is designed to accelerate particles beyond limits imposed on older machines by relativistic forces. The California machine, the fourth of its type, and much the most powerful, is designed specifically to accelerate electrons, which gain "relativistic mass" very rapidly as their speed increases and which cannot be accelerated effectively at all in most types of particle accelerators. Because electrons are poor projectiles, they are not used directly in bombardment experiments, but after acceleration are converted to X-rays of equivalent energy.

The production of mesons by protons was made possible by modification of the 184-inch cyclotron, which had previously accelerated only deuterons and alpha particles, to accelerate protons as well. Protons from the modified cyclotron have also generated a beam of 350 million-volt neutrons. With the synchrotron and rebuilt cyclotron, the Radiation Laboratory has an array of instruments able to accelerate nearly all the fundamental particles into the cosmic-ray energy range.

Chemistry of Heredity

A SERIES of discoveries which furnish an important clue to the ultimate nature of the mechanisms governing inheritance and the differentiation of tissue has been made by A. E. Mirsky and Hans Ris of the Rockefeller Institute for Medical Research.

Chromosomes—the bearers of heredity—are composed largely of proteins and the complex compound desoxyribonucleic acid. Little has been known about the role of these compounds in the

chromosomes. Chromosomes, found in virtually all cells of the body, are known to initiate and regulate the complex processes of growth. By careful microchemical analysis, Mirsky and Ris determined that every set of chromosomes in the body cells of an individual contains exactly the same quantity of desoxyribonucleic acid. Sperm and egg cells contain precisely half this amount; thus their finding provided chemical confirmation of the well-known fact that the chromosomes divide when sperm and egg cells are formed. The quantity of protein in the chromosomes, on the other hand, is not the same in all body cells but depends on the type of cell (liver, muscle and so on) This supports the view that differentiation of tissues results from different nucleoprotein-enzyme complexes in different types of cells.

Mirsky and Ris, after studying a wide variety of vertebrates and invertebrates, found that with certain exceptions the quantity of desoxyribonucleic acid in each cell is constant for all individuals of a species but varies from species to species. This suggests that, just as variations in chromosome protein may underlie tissue differentiation, variations in desoxyribonucleic acid may be the chemical basis for the differentiation of species.

AMA Health Plan

THE American Medical Association is reported to be preparing bills of its own to implement a 12-point national health program which it proposed last month as an alternative to national health insurance and the health program of the Truman administration.

The AMA proposes the establishment of a Federal department of health headed by a secretary of Cabinet rank who must be a doctor of medicine. The department would take over all medical and public health activities of the Federal government except the military activities of the armed forces' medical services. The other 11 points in the AMA program are. 1) Government support of medical research through the agency of a national science foundation, 2) extension of the present system of voluntary hospitalization and medical care insurance; 3) establishment of a medical care authority in each state to administer state and Federal appropriations, which would include medical care subsidies for the needy; 4) establishment of rural diagnostic and hospital centers; 5) expansion of local public health services; 6) support of the already authorized Federal mental health program; 7) a national health education program; 8) Federal support for the care and rehabilitation of the aged and the chronically ill; 9) integration of veterans' medical care facilities with those of other agencies; 10) greater emphasis on industrial medicine and accident prevention; 11) Federal aid for medical and allied schools.

The AMA made public its program a few days after 138 prominent physicians had sent it a public letter. The letter criticized the Association's failure to develop an effective program for improvement of the nation's health and announced the signers' refusal to pay the $25 assessment ordered by the AMA to finance an educational campaign against national health insurance The Kings County Medical Society, among others, has voted disapproval of the assessment. AMA officials have now ruled that no action will be taken against doctors who refuse to pay it

Columbia Valley Authority

A BILL to set up a Columbia Valley Authority similar to the Tennessee Valley Authority is being prepared for introduction into Congress at the request of the President.

If the bill passes, the CVA will launch a coordinated power, irrigation, navigation and flood control program for the Columbia River and its tributaries The Columbia system, by virtue of its huge volume of water and swift falls, is the greatest water power reserve in the world As a start, the Authority would take over Grand Coulee and Bonneville Dams and the wires of the Bonneville Power Administration for integration into a power grid covering Washington, Oregon, Idaho and part of Montana. The generating capacity already installed at these dams totals 1.5 million kilowatts. This would be more than doubled by additional generators to be installed at Grand Coulee and by completion of three huge dams now under construction—Hungry Horse in upper Montana, Anderson Ranch in Idaho and McNary on the Washington-Oregon boundary. Eventual development of still other dam sites would raise the Columbia's generation to more than seven million kilowatts—one-eighth the present capacity of the entire electric power industry in the U. S.

148 Million People

A RECORD low death rate and the second greatest number of births in our history combined to raise the population of the U. S. to 148 million at the beginning of 1949 If the present rate of growth continues, by 1950 our population will pass 150 million

According to estimates by the Metropolitan Life Insurance Company, the death rate last year was 9.9 per 100,000 —about one and a half per cent below the rate for 1946, the year with the lowest previous rate. The drop resulted largely from the continuing decline in deaths from tuberculosis and pneumonia, the mortality from which was respectively a fourth and a sixth lower than in 1946. Deaths from the communicable diseases of childhood were near the vanishing point Maternal deaths also set a new low Only deaths from cancer and the cardiovascular-renal diseases showed a rise The average length of life was 67.16 years, as compared with 66.86 years in 1947.

In 1948 there were 3,650,000 births—only 260,000 below 1947's record. The population gain during the year was nearly two and a half million. For the decade 1940-50, the U. S. population increase will probably total 17 million, the largest gain in any decade in our history Population experts believe that this record is not likely to be surpassed in any decade in the foreseeable future

Foreign Medical Graduates

THE Federation of State Boards of Medical Examiners has proposed that no doctors graduated from foreign medical schools since 1935 be permitted to take examinations for licenses to practice in the U S. The Federation also asked the Veterans Administration to cease paying the expenses of veterans studying medicine abroad. Only Canadian medical schools would be exempt from these interdictions.

The Federation said that the proposed prohibitions were necessary "to keep medical standards at a high level and thereby protect the public." It asserted that "it is generally known that there has been a marked deterioration in medical teaching and equipment" in medical schools abroad since 1935. An apparent disagreement with this conclusion, so far as Scandinavian medical schools are concerned, has been expressed in reports by Drs Albert B Sabin and Eugene B. Ferris, Jr, of the University of Cincinnati College of Medicine, who made postwar surveys of Scandinavian and Polish schools. They found the Danish, Norwegian, Swedish and Finnish medical schools "of such caliber that the people licensed there should be admitted to examination for licensure here"

World Economy

THE WORLD production of all goods and commodities was about 10 per cent higher in 1948 than in 1947 and 20 per cent higher than in 1937, according to the United Nations Department of Economic Affairs Some of the acute postwar shortages of goods and food are nearing an end.

Nearly all countries last year had such large crops that the world food situation has been "substantially improved." Industrial production, partly because of technological advances and increased labor productivity, recorded an even greater gain. Output in the first nine months of the year showed increases of 11 and 32 per cent over the corresponding periods of 1947 and 1937.

The improvement was by no means

uniform in all countries, however Most of the gain in industrial production was registered in Europe and the U. S. S. R. Severe shortages of manufactured goods continue in many parts of the world, notably in Asia and Latin America.

Housing

A CAREFUL study of the world housing situation made at the direction of the UN General Assembly finds that a thoroughgoing revolution in construction methods is necessary to overcome the planet-wide housing shortage The report proposes an international reorganization of the building industry.

Europe alone has an accumulated deficit, going back to the First World War, of 14 million housing units. To provide only as much space per capita as was available in 1939 would take 22 years of construction at double the prewar rate. At that rate Sweden might return to the position of 1939 in six years, but Greece would need 154 years, and some European countries would never close the gap between the housing available and the needs of their increasing populations. Yet with present building methods, even this minimum construction rate is probably impossible because of lack of sufficient building materials

The authors of the report suggest that one indispensable requirement is an international program to promote the development and use of prefabrication techniques One contributor, Ernest Weissmann, director of the Industry and Materials Division of the UN Economic Commission for Europe, proposes the creation of a special international agency for research on housing.

U. S. S. R. Quits WHO

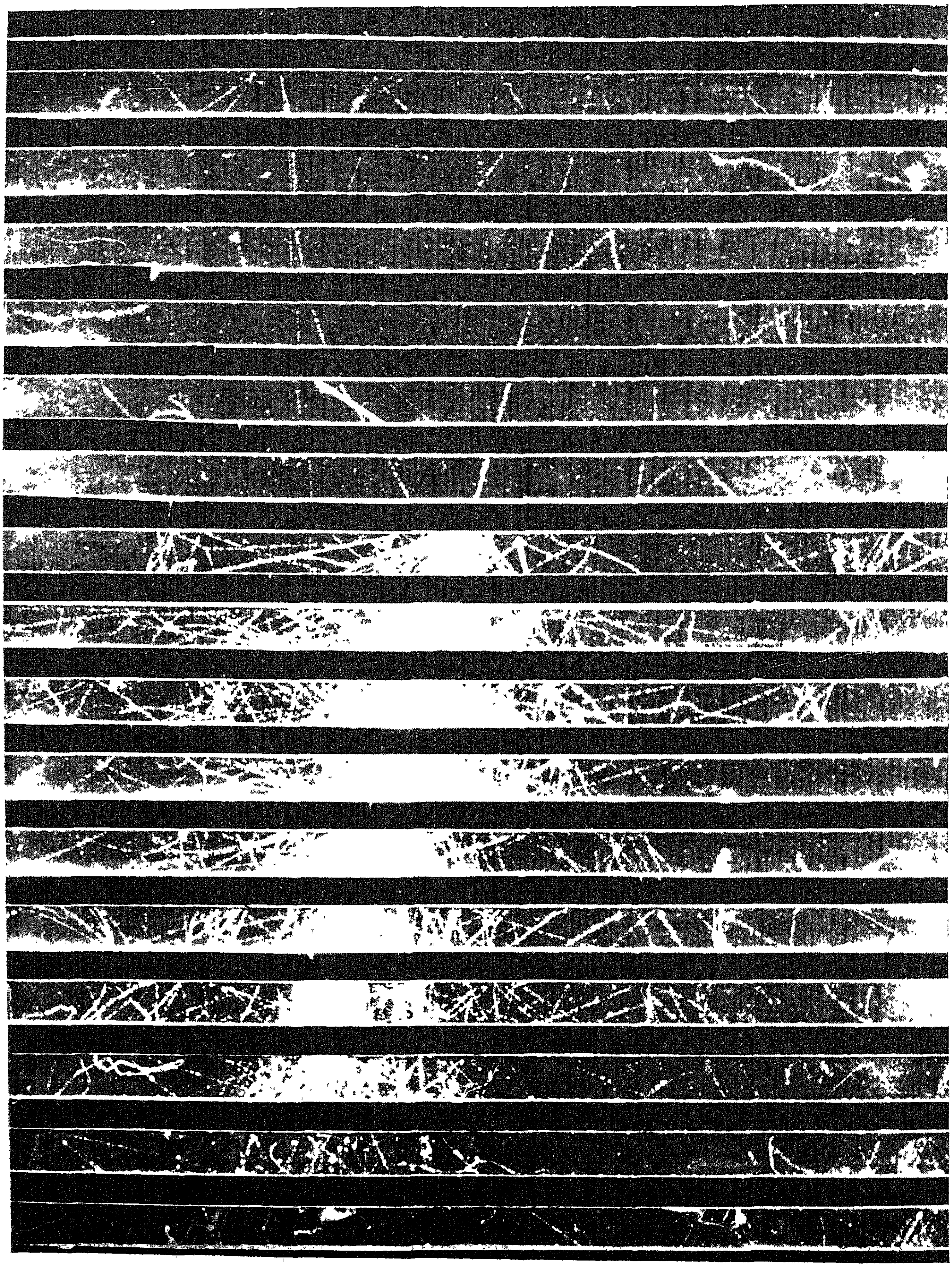
THE U. S. S. R., White Russia and the Ukraine have withdrawn from the World Health Organization, the only new specialized UN agency in which they still held membership. In notices of resignation to WHO, they said that the organization had failed to accomplish the tasks set for it by the World Health Conference in 1946 and that maintenance of its "swollen administrative machinery involves expenses which are too heavy for member states to bear." The annual assessment for the Soviet republics has been $350,000. The U. S. S. R. played an active role in WHO at the beginning but withdrew from work in its technical committees at about the middle of last year.

Meetings in April

AMERICAN Philosophical Society Philadelphia. April 21-23.

National Academy of Sciences Washington. April 25-27.

American Physical Society. Washington. April 28-30.



SHOWER OF PARTICLES is released by a high-energy particle entering cloud chamber of W. B. Fretter at the University of California. Within the chamber are 16 half-inch lead plates which compress into a few inches events that are spread out over much greater distances in air. The lead plates are here seen from the edge. The initial particle slants in from upper right. Below it is a burst of electrons and penetrating particles.

COSMIC RAYS

On its majestic journey through space the Earth passes through a harsh rain of atomic particles. Presenting a brief review of what is now known about the phenomenon

by George W. Gray

THE COSMIC RADIATION has been described as a bombardment, but this picture should not be taken literally. The Earth is not a target at which some celestial artillery aims its missiles. Our planet is a traveler in a universe in which all things move. As it rides its vast curve through space-time, the Earth continually encounters moving objects of many kinds: meteors and other planetary fragments, ultra-high frequency radio impulses from distant sidereal generators, the light of the Sun and stars, as well as the high-energy particles known as cosmic rays.

Cosmic rays are something Out There, like the rain into which a man goes—only it would be necessary for the rain to fall upward and sideways, as well as down, to provide an analogy to cosmic rays. For these enigmatic particles strike the Earth from all directions, and seemingly they are everywhere present in that part of the firmament through which we are moving.

The raindrops in any given rainstorm are fairly uniform and fall with approximately constant sizes, masses, and velocities. Detectors have recorded such diverse particles as photons, electrons, positrons, mesons, protons, and heavier nuclear fragments. A few of those which reach sea level are primary cosmic rays, but most of them are offshoots resulting from collisions with air molecules. From the top of the atmosphere to its bottom at sea level, the absorbing power of the air is equivalent to that of a jacket of lead 40 inches thick. Yet cosmic rays carrying 2,000 million electron volts have been measured at sea level. There is evidence that far higher energies are projected through the atmosphere, for cosmic rays have been detected in mines after penetrating several hundred feet of soil and rock. The upper limit of the primaries' energy is not known, but nuclear explosions and other violent events produced by particles carrying 10,000 million mev have been recorded, and there is circumstantial evidence for the existence of primaries moving with the force of at least a million million mev. By contrast, the energy released in the fission of the uranium atom is a puny 200 mev.

The "Natural Leak"

No one knows how long the Earth has been traveling through this cosmic rainstorm. The effect was discovered quite accidentally less than 50 years ago. The first hint came from the electroscope. This simple instrument, which had been used for more than a century to detect the presence of electricity, was employed by Marie and Pierre Curie, Ernest Rutherford, Frederick Soddy and others to measure radioactivity. Essentially the apparatus consists of two thin foils of gold leaf mounted within a glass jar on a well-insulated metal rod that protrudes from the jar. By rubbing the outside end of the rod, a positive electric charge is communicated to the system, and because of the charge the two gold leaves repel each other and stand out from the rod like extended wings. The gamma rays emitted by radioactive elements knock electrons out of air molecules, the electrons flow to the rod of the electroscope, neutralizing its charge, and in consequence the gold leaves settle down. The radium investigators found that the time required for the electroscope to lose its charge was a measure of the intensity of the gamma rays—provided, of course, there was no other influence also affecting the electroscope.

ACKNOWLEDGEMENT

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But it appeared that there was some other influence. When the instrument was carefully isolated from all known sources of contamination, and a charge applied, the gold foils would stiffen and stand out from the electrode for days, but in time the charge oozed away and the foils drooped. After some experimenting the physicists found that they could predict the magnitude of this "natural leak" fairly closely; therefore they could allow for it and measure the gamma rays with a good approximation. This took care of the immediate problem of studying radium, but the source of the leak remained unexplained and haunted the investigators.

They assumed that the leak was caused by the natural radioactivity of the Earth. It was known that rocks, clays, soil and even the lower atmosphere carried minute traces of radioactive elements. Conceivably the radiation given off by these stray atoms might reach the electroscope. But three inches of lead would stop the most powerful gamma rays, and it was an easy matter to surround an electroscope with thick slabs and see what happened. It took the lead-jacketed instrument longer to lose its charge, but the leak was still there. Then the Canadian investigator, John C. McLennan and his associates carried an electroscope out on the frozen surface of Lake Ontario. They reasoned that the several hundred feet of water beneath the ice would provide a shield against the radioactive Earth; and indeed it was found that the electroscope did discharge more slowly, but even far out on the lake the extended leaves eventually collapsed.

In Paris a Jesuit physicist, Theodor Wulff, carried an electroscope to the top of the Eiffel Tower, an altitude of 300

PARTICLE	CHARGE	MASS
ELECTRON	–	1
POSITRON	+	1
PROTON	+	1836
NEUTRON	0	1836
MESON PI	–	284
MESON PI	+	284
MESON MU	–	215
MESON MU	+	215
NEUTRAL MESON	0	?
NEUTRINO	0	0?

GLOSSARY of fundamental particles for the reader includes new measurement by University of California groups of the meson masses.

meters (984 feet). Wulff found that up there his instrument continued discharging, but at a rate about one-half that he had measured down on the ground. To get still higher, Albert Gockel of the University of Fribourg obtained a balloon. He made three ascensions in 1910-11, once to an altitude of 4,500 meters, and found that the natural leak was still detectable.

Reports of these results reached a young Viennese physicist, Victor Francis Hess, and in the spring of 1911 he resolved "to attack the problem by direct experiments of my own." First he made a number of tests on the ground, setting out 1,500 milligrams of radium and measuring the distances at which gamma rays could be detected through the air. From this study, Hess concluded that gamma rays from the ground "are almost completely absorbed at 500 meters above the ground" Next he designed and built several detecting instruments and took them up in a series of balloon flights. As the balloon rose, the natural leak grew progressively smaller until an altitude of 500 meters was reached, after that the effect increased, at 1,800 meters it was equivalent to the value at the ground; and at 5,900 meters it was more than twice the ground value This discovery of the increase of the discharge with altitude convinced Hess that there must be "a very penetrating radiation coming mainly from above and being most probably of extraterrestrial origin." Twenty-five years later his perspicacity was rewarded with a Nobel prize. But at the time only a few physicists noticed his report, and even fewer bothered to look further into this strange "Hohenstrahlung" (high altitude radiation)

One of the few who were keenly impressed was Werner Kolhorster, an assistant in the department of physics at the University of Halle. He resolved to repeat the tests at higher altitudes, obtained a larger balloon, and ascended to 9,000 meters At that elevation Kolhorster found that the electroscope leaked its charge about 13 times as fast as at sea level The coming of World War I interrupted these researches, and little more was done by anyone until after the war. Then in the early 1920s Kolhörster resumed his studies, and in America a new investigator joined the search Robert Andrews Millikan of the California Institute of Technology.

Millikan wondered what the radiation effect would be in the stratosphere. It was out of the question for an observer to ascend to stratospheric heights, but readings might be obtained by sending up a self-registering apparatus. Within a few weeks Millikan and his research assistant, Ira Sprague Bowen, had devised an electroscope that could be wound up like a clock and had a driving mechanism to recharge it at measured intervals Attached to it was a camera which photographed a continuous record of the status of the electroscope charge. The whole thing weighed only seven ounces, light enough to be lifted to high altitude by two sounding balloons Each balloon, filled with hydrogen, was four feet in diameter when inflated. Millikan and Bowen launched the combination from Kelly Field, near San Antonio, Texas, in April of 1922 The balloons rose to 15,500 meters (nearly 10 miles) and drifted for three and a half hours Then one balloon burst, according to plan, and the remaining balloon eased its load gently to the ground, landing near Houston.

The experiment provided additional evidence of the strange propensity of the ascending electroscope to increase the rate at which it leaked its charge. The phenomenon presented many questions. For one thing, how penetrating was the radiation that caused the discharge? Millikan now made that his chief study. Kolhorster also concentrated on it, and presently similar experiments were under way in both Europe and America

Millikan, G H. Cameron, and R. M Otis mounted electroscopes in waterproof containers, sank them meter by meter in mountain lakes, and found that the effect coming from above was appreciable at the greatest depths they were able to test. Kolhörster and his coworkers took electroscopes into the Alps, measured the effect on top of glaciers and then in crevasses deep under the glacial ice. The mysterious effect had at least 18 times the penetrating power of the hardest gamma ray. There could no longer be any doubt of its outside origin, and in 1925 Millikan named this penetrating something "the cosmic rays."

Waves or Particles?

But naming the foundling did not explain its nature or determine its origin, and now the searchers centered their efforts on identifying the rays. Were they electromagnetic waves like the gamma rays shot out of radium? Or were they charged particles like the beta and alpha rays also ejected by the radioactive elements?

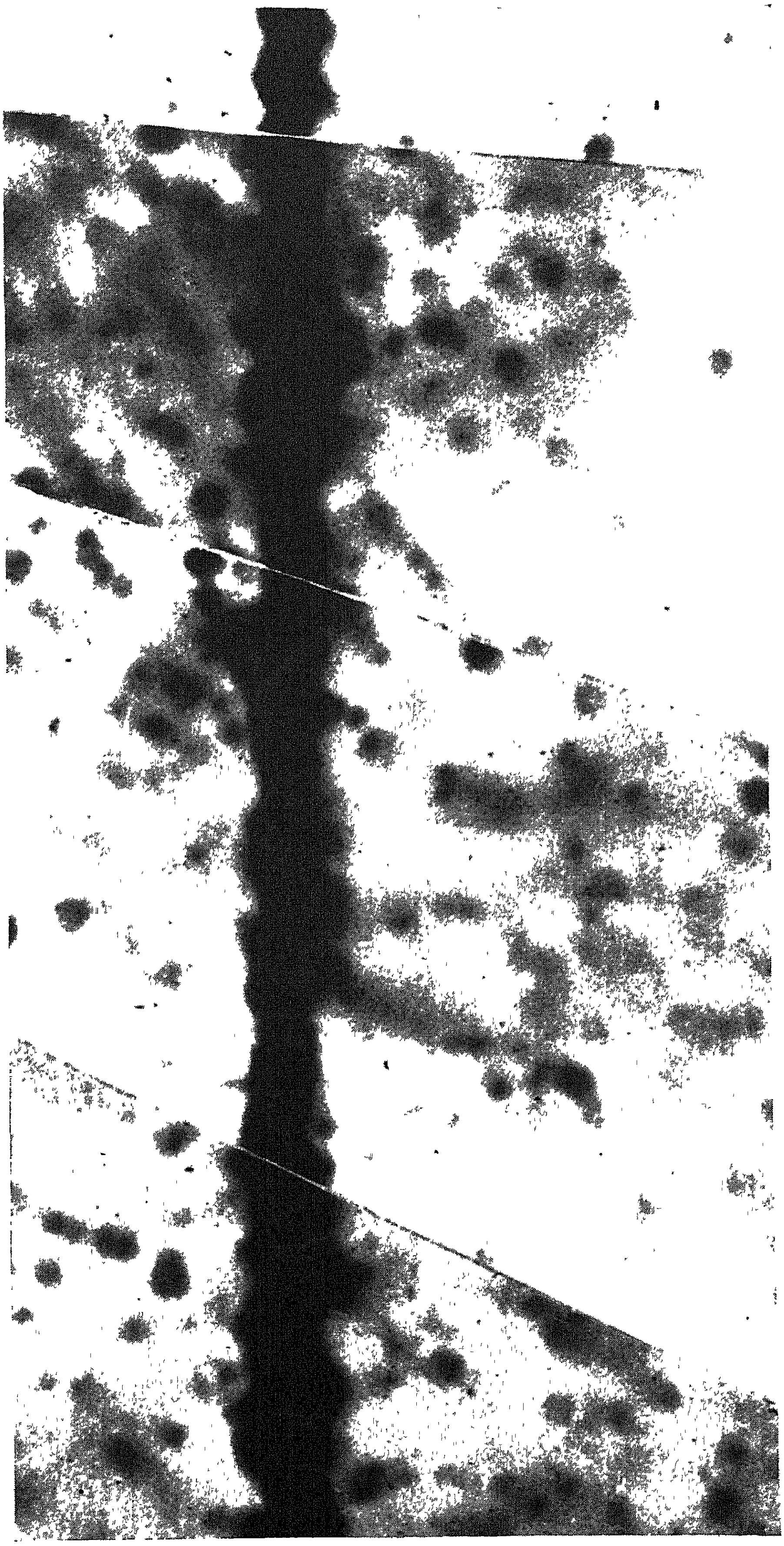
At first scientists were inclined to favor the first hypothesis, and there were ingenious speculations as to what processes would be able to propagate such energetic waves through vast distances in space. But it was not long before Kolhorster and his associate W. Bothe obtained evidence which hinted that at least some of the cosmic rays were charged particles. When the cloud chamber was turned to the investigation, the hint became a certainty, for this instrument makes the paths of charged particles visible.

In the early years of cosmic-ray research, the most powerful magnet avail-

able was not able to bend the tracks of many cosmic rays streaking through cloud chambers Carl D. Anderson, working with Millikan at California Institute of Technology, hit upon the scheme of inserting a plate of lead horizontally across the center of the chamber This layer of dense metal absorbed energy from the incoming cosmic rays, and Anderson found that then his magnet was able to bend more of them. In some instances he photographed tracks that entered the lead plate with a slight curvature and emerged with a sharper curvature. By these means Anderson measured rays with energies of thousands of mev, and in the course of the studies discovered the fundamental particles now called the positron and the meson Charged particles are the only bodies which will swerve under the influence of magnetism, thus it was clear that the positron, the meson, and other cosmic rays that traveled through the magnetic field in curving paths were material particles.

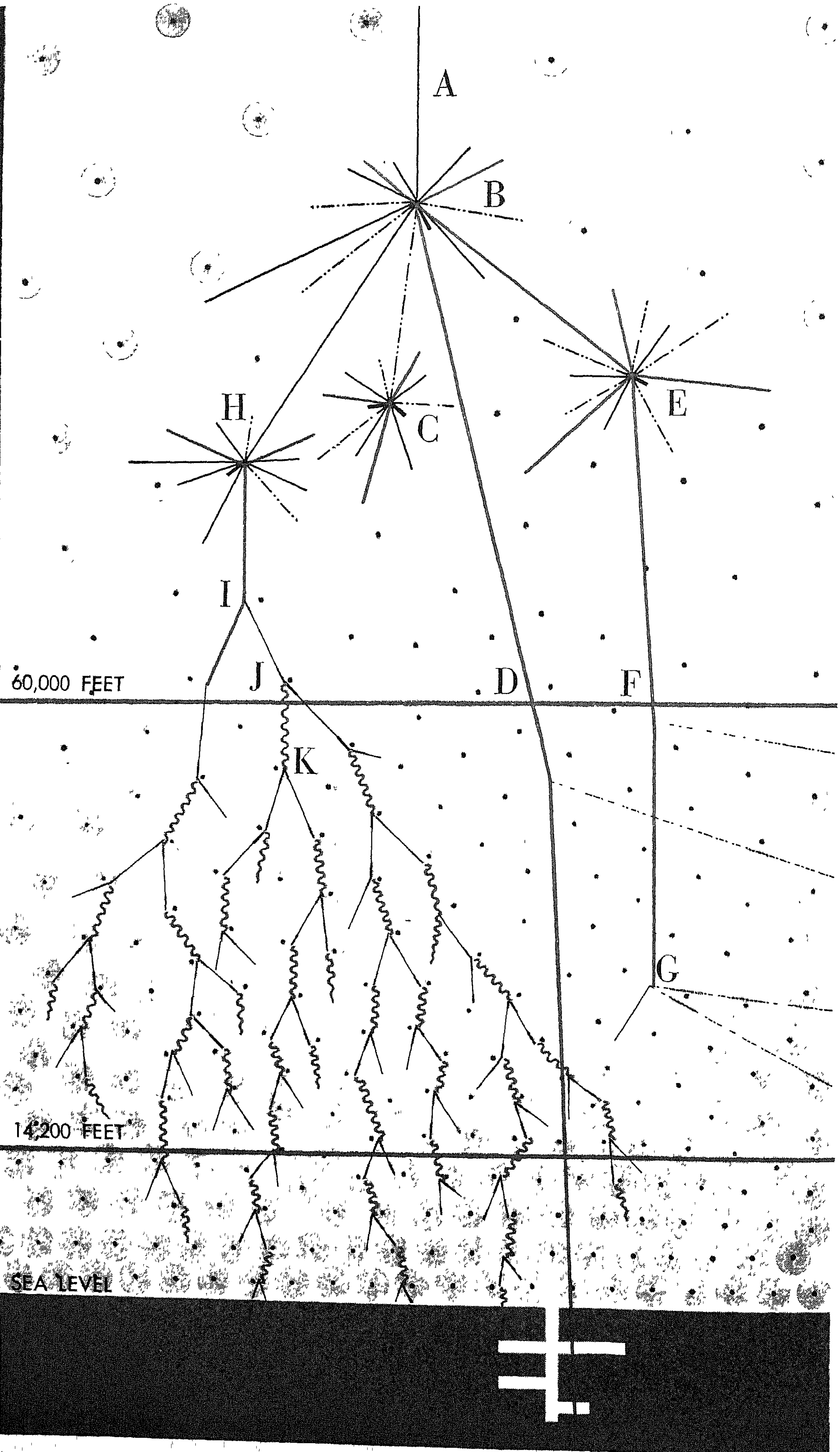
Meanwhile it had been pointed out that the Earth itself might provide evidence of the nature of the rays. Our planet is a big magnet, with one magnetic pole in northern Canada and the other in Antarctica, and the lines of force connecting these poles reach into space. If the incoming cosmic rays were radiant energy, like gamma rays, they would of course carry no charge and therefore would pass through the Earth's field without deflection But if they were charged particles, they would bend to the terrestrial magnetism just as the charged particles passing through the cloud chamber respond to a magnetic field. Indeed, it was possible to calculate how much energy a charged particle needed to get through the Earth's field. Calculations showed that the value in high latitudes—that of Chicago, for example—was about 2,000 mev for protons moving vertically down; in intermediate latitudes, e.g., Los Angeles, it was about 5,000 mev; and at the equator, about 15,000 mev. On this reckoning, protons with energies less than about 2,000 mev would be turned aside completely and therefore would never get into the atmosphere at any latitude (except near or directly over the magnetic poles), while only those carrying more than 15,000 mev would be able to resist the magnetic deflection sufficiently to penetrate at the equator. The cosmic radiation, therefore, should grow more intense as the observer traveled toward the poles. This line of reasoning prompted the investigators to look for an effect that was correlated with changes in latitude.

It was found by J. Clay in the course of making an ocean survey for the Dutch Government. This Amsterdam physicist carried an electroscope on his ship, and as he traveled away from the equator the discharge rate increased. In 1932, Ar-



COMPOUND NUCLEUS of huge energy left this track in a pile of photographic plates. The appearance of compound nuclei as well as protons among primary cosmic rays is a major new discovery. Plates were sent in balloons to heights of 80,000 to 100,000 feet by University of Minnesota group.

	Compound Nuclei (primaries)	Protons (primaries)	Protons (secondaries)	Neutrons	Mesons	Electrons
60,000 FEET	25	6,350	17,000	15,000	12,000	48,000
14,200 FEET	Undetermined	Undetermined	300	300	2,600	1,900
SEA LEVEL	Undetermined	Undetermined	20	20	1,100	180



thur H. Compton, then at the University of Chicago, organized an international survey which made observations on all continents, and on many islands, seas, lakes and mountains. Compton's observations showed that the variations in cosmic-ray intensity followed the Earth's magnetic latitude, as would be the case if the rays were charged particles

There is also a west-to-east effect. It was discovered independently by Bruno Rossi in Italy and Eritrea, and on this continent by Luis W Alvarez, then of the University of Chicago, and T. H Johnson of the Bartol Research Foundation Both Alvarez and Johnson made their observations near Mexico City, for it is in a latitude favorable to such an inquiry. Each investigator used a cosmic-ray "telescope" This apparatus is a combination of two or more cosmic-ray detectors mounted in vertical series, one on top of the other. The combination is wired in such a way that only when a cosmic ray streaks through the entire series of detectors does the instrument record the event. By pointing the telescope toward the sky at various angles, Alvarez and Johnson were able to show that in Mexico City about 10 per cent more radiation came from the west than from the east The effect changes with latitude, and in the neighborhood of Chicago it is about two per cent on the ground.

This west-to-east effect is a highly important clue, because electromagnetic theory tells us that the influence of the Earth's magnetic field bends positive charges in one direction, and negative charges in the opposite. The preponderance of cosmic rays curving down from the west suggests that the primary rays are predominantly of positive charge With each discovery the case for the particle hypothesis grew stronger.

The Ion Traps

The only information we possess about cosmic rays is in the debris left by their interactions with other material particles. The incoming rays mutilate atoms of the air and of other materials through which they pass, and it is by defining the mutilations and measuring the energies involved that physicists have learned all that is known of cosmic rays. Sometimes the mutilation is relatively minor. an electron is knocked out of its orbit in an atom, thereby depriving the atom of one negative charge and leaving it with positive charge. The electron is equally unbalanced by this rude separation. Thereafter both mutilated atom and detached electron are ions, *i e*, wanderers, and any charged object in the neighborhood will attract one or the other of them.

Sometimes the mutilation is more drastic. The incoming particle may hit the nucleus of an atom head-on and knock it into many fragments, smashing out mesons, protons, neutrons and possibly larger pieces Most of the nuclear fragments will be either positively or negatively charged, and therefore they, too, will respond to the attraction of any charged object in the neighborhood.

In consequence of this all-important role of ionization in revealing the presence and properties of cosmic rays, the researchers are primarily occupied with the business of setting up charged devices to serve as ion traps. The oldest of these is the previously mentioned *electroscope* The next ion trap to be used was the *ionization chamber*. This is an insulated vessel with two electrodes. The chamber is filled with air or another gas, and by imposing a positive charge on one electrode and a negative charge on the other, a trap is set to attract any positive or negative ions that chance to form in the gas The flow of the ions constitutes an electric current, and the strength of the current indicates the degree of ionization

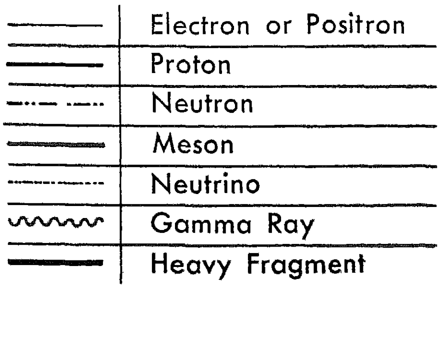
The *Geiger-Müller counter* is a modified ionization chamber. It employs a higher voltage than an ordinary ionization chamber, and the voltage is so adjusted that the flight of a single ion will cause a pulse of electricity to flow through the system. Thereby it records each event of ionization and enables the observer to count them.

Cloud chambers and the more recently developed *photographic emulsions* render the paths of ionization visible. The more massive the ion, the more slowly it moves and the greater is the number of secondary ions it leaves to mark its path. An electron carrying half a million volts will produce about 30 pairs of ions in moving one centimeter through the gas of the cloud chamber, whereas the 8,000-times more massive alpha particle may produce as many as 34,000 ion pairs in going the same distance. The width and density of the cloud-chamber tracks are therefore of significance. And this is equally true of the tracks impressed on the photographic emulsion when a cosmic ray plows a track of ionization through its molecules of gelatin and silver. Indeed, as Serge A Korff of New York University has pointed out, "photographic emulsions may be thought of as similar to a continuously sensitive cloud chamber"

These five types of ion traps are serving as eyes with which to seek out the rays and as hands with which to sort and classify them Rockets carrying ionization chambers, counters, photographic emulsions, and in some instances cloud chambers, have pushed the inquiry to altitudes of more than 110 miles, although their flight time is rarely more than three minutes. Sounding balloons have lifted ion traps to altitudes of 20 miles and kept them aloft for hours, recording the cosmic ionization in that zone Recordings have been made in airplanes at elevations of six to seven miles, this technique having the advantage of permitting the observer to keep watch on what is happening. Several laboratories have been established on mountains or high plateaus at altitudes of two to three miles, and these permit the use of more massive equipment and longer periods of continuous observation than is possible with the rocket, the balloon, or the airplane. Finally, of course, there is the greatest activity of cosmic-ray research down at ground level; and for absorption studies use is made of mines and other subterranean or submarine depths.

Primaries and Secondaries

On the average some 21,500 cosmic rays fall per minute upon each square foot of the top of the atmosphere at latitude 41 degrees (which in the Northern Hemisphere is that of Chicago). Over the equator the number is less, and over the poles it is greater. Taking into account the geomagnetic effect, it is estimated that the total number of primary cosmic rays falling upon the whole at-



ONE PRIMARY RAY may cause events outlined on opposite page. Some 21,500 protons and 79 compound nuclei fall on each square foot of the upper atmosphere per minute. The number of primaries and secondaries at lower altitudes is shown in the table at the far left. The gray circles represent atoms in air. Primary ray (A) shatters the nucleus of an air atom (B). From this "star" comes a neutron that disrupts another nucleus (C). A positive *pi* meson (D) shot out by the first star may decay into a *mu* meson with the emission of a neutrino. A negative *pi* meson from the first star may produce another *pi* meson (E) which also decays into a *mu* meson. The *mu* meson may in turn decay into an electron with the emission of two neutrinos (G). The star resulting from a proton (H) here manufactures a meson that knocks an electron from its orbit (I). The electron then begins a "shower" (J and K).

mosphere is about two million million million per second.

Inasmuch as hydrogen is the most abundant element in the universe, the most numerous particles encountered in free space should be protons, the nuclei of hydrogen atoms. And they are. One would also expect to find an occasional nucleus of a heavier atom, and this expectation was realized last spring by physicists from the Universities of Minnesota and Rochester. Examining some thick-emulsion photographic plates that had been exposed to cosmic rays at altitudes of 80,000 to 100,000 feet, they found heavy tracks of ionization that could be made only by particles heavier than protons. This discovery, perhaps the most important cosmic-ray find of 1948, was made by Phyllis Freier, E. J. Lofgren, E. P. Ney, and Frank Oppenheimer, of Minnesota, and H. L. Bradt and S. Peters of Rochester.

The sounding-balloon flights on which these compound nuclei were photographed were made from Camp Ripley in northern Minnesota, and the results were soon confirmed by Marcel Schein and his co-workers at the University of Chicago. At Camp Ripley the compound nuclei range in mass from about four, that of helium, to about 96, the mass of molybdenum. At Chicago the photographs have picked up no tracks of particles heavier than about mass 36; and this failure of the more massive nuclei to get through appears to be a latitude effect, since Chicago is about five degrees south of Camp Ripley. It is significant that at both latitudes very few tracks are found of particles between mass four (helium) and mass 12 (carbon). These intermediate masses are those of lithium, beryllium and boron—and cosmologists who weigh the abundance of elements in the universe report that lithium, beryllium and boron are very scarce. A close relationship between cosmic-ray physics and astrophysics is indicated, and several cosmic-ray colloquia planned for 1949 are inviting astronomers to participate.

The compound nuclei constitute only a tiny minority among the primary cosmic rays. Estimates based on the most reliable data now available indicate that for every square foot of the top of the atmosphere over Chicago, for example, the 21,500 primaries coming in per minute include about 79 compound nuclei. The remainder are protons.

These primaries, both protons and more massive nuclei, are traveling at various speeds. Some are moving with just enough energy to get through the Earth's magnetic field. Others are impelled by titanic energies. On the average in intermediate latitudes the mean energy of the primary cosmic rays is about 10,000 mev per particle.

Now the speed of a proton accelerated by 10,000 mev is about 185,000 miles per second. This is not far below the velocity of light. According to the theory of relativity, the mass of a moving body increases with its speed, and when the acceleration reaches the velocity of light the mass becomes infinite. An Einstein equation shows that at the speed imposed by 10,000 mev the mass of a proton increases tenfold. It enters our atmosphere with enormous momentum, and moves at a velocity which if unchecked would deliver it to the Earth's surface in a 50th of a second or less.

But seldom is a particle able to penetrate from the top to the bottom of the atmosphere. What happens after the primary cosmic rays collide with the atoms of oxygen, nitrogen and the other gases of the atmosphere is a complicated sequence of many actions and interactions. The diagram on page 32 indicates the consequences of these collisions with as much definiteness as present knowledge will permit. As the primaries enter the atmosphere they begin to lose energy through collision. At 60,000 feet less than a third of the primary protons have survived. But at this altitude an enormous population of secondary particles has been released, including secondary protons, neutrons, mesons and electrons. As the surviving primaries and secondaries plunge earthward into the relatively dense lower atmosphere, the frequency of collisions increases, and the particles rapidly lose energy. The result is that at 14,200 feet only a comparatively small number of the particles are sufficiently energetic to be detected, and at sea level the number is still less.

In detail, the sequence of events from the top of the atmosphere down to the bottom appears to be something like this.

1. The primaries (protons and compound nuclei) penetrate the atmosphere until they collide with air particles.

2. The collisions disrupt the nuclei of the atoms that are hit, causing them to splinter into heavy fragments, protons, neutrons and mesons.

3. Each nuclear fragment then becomes a secondary cosmic ray, and by the same process of collision may demolish other nuclei, creating tertiary cosmic rays. They in turn create quaternary rays, and so on, until the energy of the primary ray is dissipated.

4. Four kinds of mesons—the heavy *pi* mesons of positive or negative charge and the lighter *mu* mesons, also positively or negatively charged—are among the secondary cosmic rays set into action by the impact of the primaries. How the meson behaves as a cosmic ray depends on what kind it is. A positive *pi* will travel a distance ordained by the magnitude of its energy and then disintegrate, releasing a positive *mu* meson. But if the *pi* is negatively charged, the probability is that it will be attracted by the positive charge of some atomic nucleus, plunge headlong into it, and thereby cause the invaded nucleus to explode. The explosion may eject a *mu*. What the *mu* does also depends on its electrical character. If it is positively charged, it will decay with the emission of a positive electron. If negatively charged, the meson may be captured by the nucleus of some atom of the air, and eventually be absorbed by it, thereby releasing an electron. Or, by collision, this negative *mu* meson may knock a satellite electron out of its orbit, and impart its energy to the caroming electron. Thus *pi* mesons produce *mu* mesons; and *mu* mesons by their various processes of capture, decay, and collision create or release positive and negative electrons.

5. The resulting electrons dart downward with the energies imparted by the mesons, and as they move they in turn interact with atoms of the air. They can interact in two ways. First, by collision they may endow other electrons with excess energy and send them flying out of their atomic orbits. But a more frequent occurrence is the cascading of electron-positron pairs. This self-multiplying process, by which a single electron may set off a train of events to create hundreds and even tens of thousands of pairs of particles in a fraction of a second, is the mechanism which produces the most spectacular of all cosmic-ray phenomena: electron showers.

The Electron Showers

Soon after the cloud chamber was first applied to the study of cosmic rays, investigators found that occasionally they photographed the simultaneous tracks of two or more particles. Sometimes they would record scores of paths in a split second, all traveling parallel or nearly parallel paths. These were called air showers, since it was presumed they originated in the air some distance above the cloud chamber. Other showers were more local, with their sources apparently nearer at hand. And when the scheme of slowing down the cosmic rays by introducing a plate of lead across the cloud chamber came into use, the observers began to get local showers spraying out from the lead. Perhaps the most astonishing of the shower phenomena was that reported by the French physicist Pierre Auger. He installed a number of Geiger-Müller counters on the ground and wired them so that only when all counters were actuated simultaneously would the apparatus record. Auger then progressively increased the distance separating the counters until they were distributed over an area with a diameter of 300 meters. Even over this broad area, covering several acres, Auger found that he could still get coincidences, indicating the spread of an extensive shower originating high in the atmosphere.

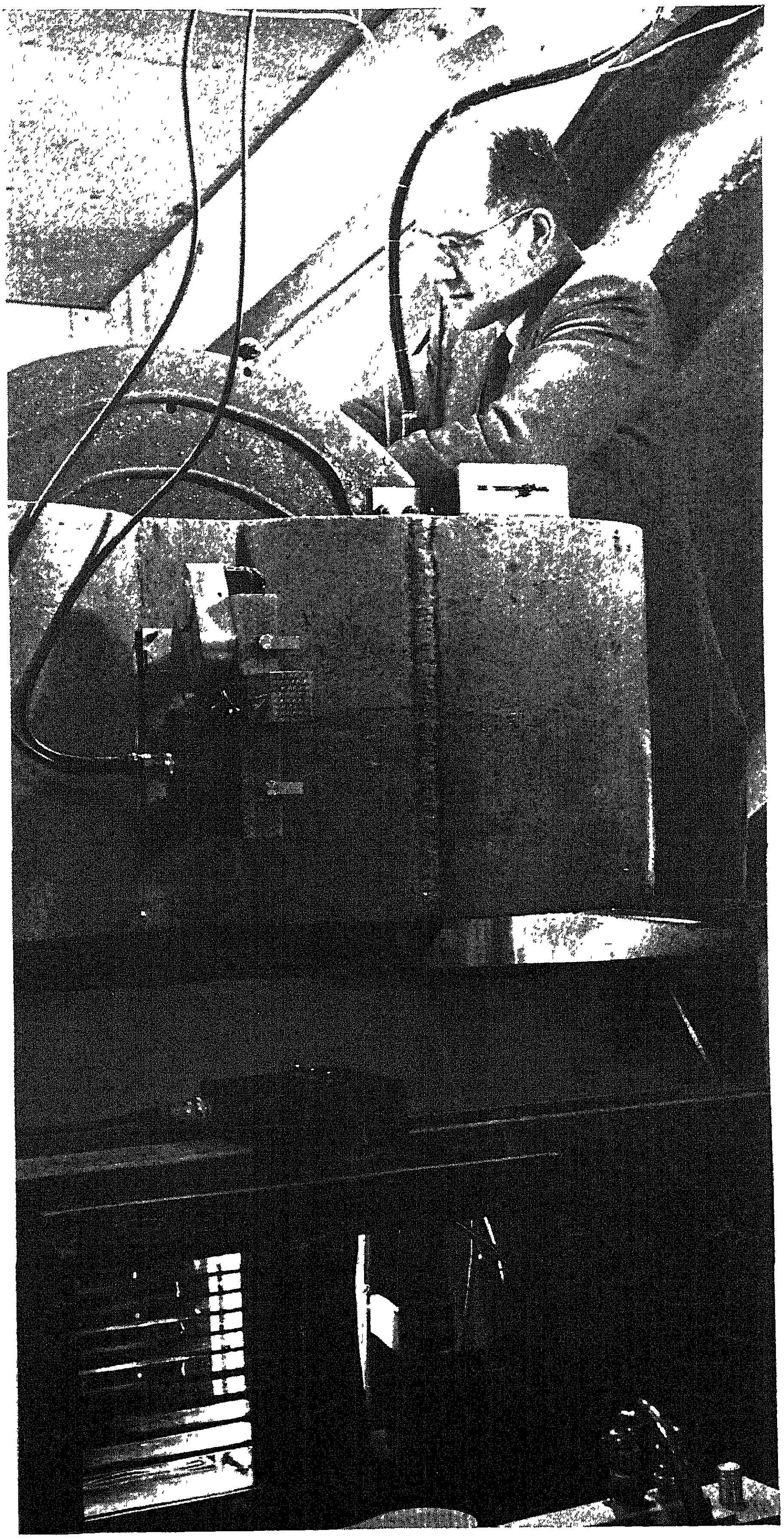
At first it was believed that showers were caused by atomic disintegrations.

They were described as bursts set off by the impact of a high-energy particle colliding, in the atmosphere, with an air molecule, or, in the lead plate, with an atom of the metal. But the particles participating in these showers proved to be almost entirely electrons, some of negative and some of positive charge, and it was difficult by the disintegration hypothesis to explain their predominance Then H. J. Bhabha and W Heitler in England and J. Robert Oppenheimer in the U. S. called attention to the quantum theory of the formation of electron-positron pairs—and it was recognized that here was a consistent explanation of electron showers

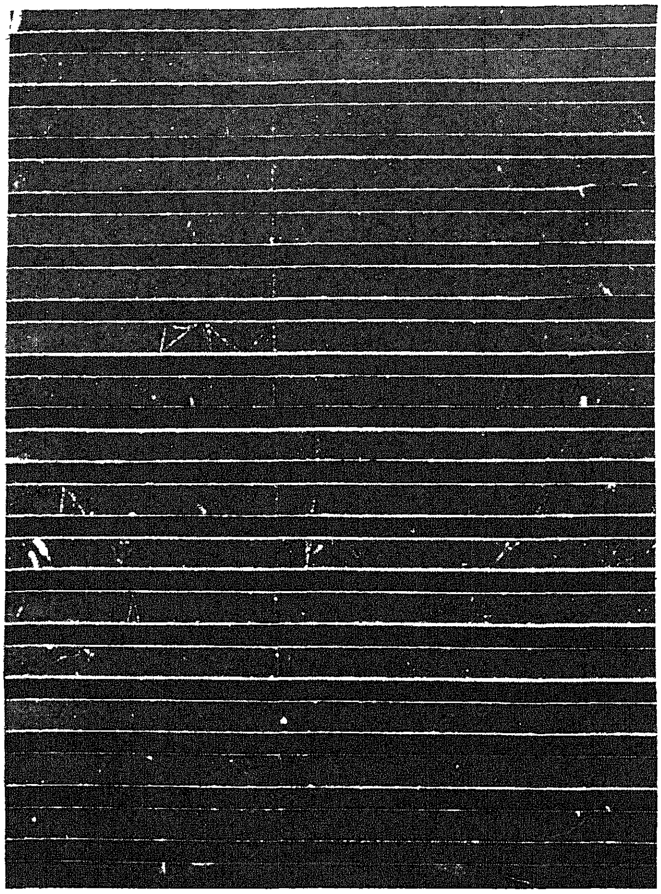
According to this explanation, the electron that the meson knocks out of an atomic orbit or creates by its own decay travels until it encounters an atom It may, of course, collide with one of the atom's satellite electrons, in which case it gives some of its energy to the struck electron and then the two speed on as two cosmic rays. But if the electron safely crosses all orbits and reaches the electromagnetic field that surrounds the atomic nucleus, an amazing transformation occurs. The impact of the electron on the electromagnetic field converts some of the electron's mass into energy, and out of the field darts a gamma ray endowed with the energy imparted by the electron The gamma ray, traveling at the speed of light, encounters the electromagnetic field of another atom, and its interaction with this field accomplishes another transformation, though of the opposite order. The gamma ray disappears, and out of the field pop an electron and a positron, the pair between them carrying the energy of the lost gamma ray. Each member of the pair soon encounters the electromagnetic field of another atom, by its interaction produces a gamma ray, the ray in turn produces a pair, and thus the shower is perpetuated.

Thus, by alternate transformations of mass into energy and of energy into mass, a single particle sets off a cascade of events. The multiplication will continue until the gamma rays degenerate to such low energy that they are no longer able to interact with an electromagnetic field. What that lower limit of energy may be depends on the density of the material through which the gamma rays move, and it is lower for heavy elements than for light. In water, for example, shower production will cease when the energy of the rays has degenerated to 115 mev, but in lead the process will not stop until the rays are down to about seven mev.

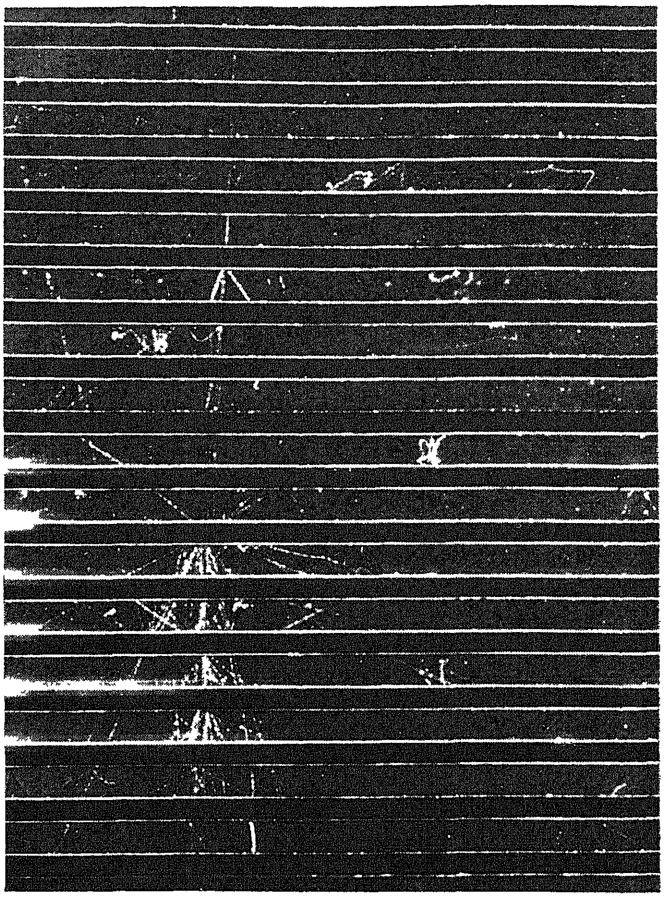
It is because of this density effect that putting a plate of lead in the path of cosmic rays will multiply the shower production. A 10,000-mev electron in passing through lead will activate its maximum shower at about four centi-



CLOUD CHAMBER used in measuring the mass of mesons is attended by Robert B. Brode at the University of California. The chamber itself is at the lower left. Above it is a magnet, the field of which bends the paths of particles. This apparatus and 184-inch cyclotron have refined meson measurements.



PENETRATING PARTICLE (*at left center*) passes through lead plates in the cloud chamber of W. B. Fretter (*page 28*). The particle is probably a meson.



SHOWER OF ELECTRONS and some penetrating particles is caused by a particle that has passed through most of the plates. Electrons leave the short tracks.

meters' distance from the upper surface, producing about 100 particles and about 150 gamma rays. But if the electron carries 1,000 million mev of energy it will produce a shower of about 10 million particles, the maximum cascade effect being reached in eight centimeters of lead. By contrast, a shower initiated by the same 1,000 million-mev electron in water would not reach its maximum until 800 centimeters had been penetrated.

But the cascade is not able to proceed indefinitely. As the thickness of the screen is increased, the population of the shower decreases until finally the absorption is complete. A block of lead 15 centimeters thick will absorb the heaviest electron shower.

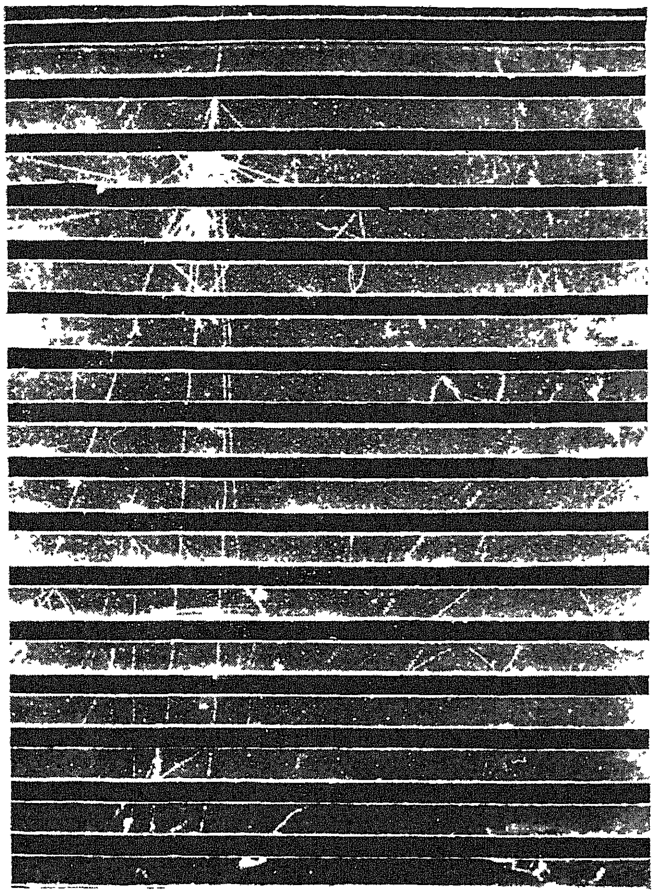
It is significant, however, that an occasional particle gets through even this dense screen, and 15 centimeters of lead is therefore the criterion for separating cosmic rays into two principal components. Whatever is stopped is called the *soft component*. This may include some slow protons and mesons of low energy, but predominantly the soft component is made up of electron-positron pairs and their gamma rays. Whatever passes through the 15 centimeters is the *hard component*, and here again protons may be found and also neutrons, but the greater proportion of these highly penetrating particles—perhaps 90 per cent of them—are high-energy mesons.

The Penetrating Mesons

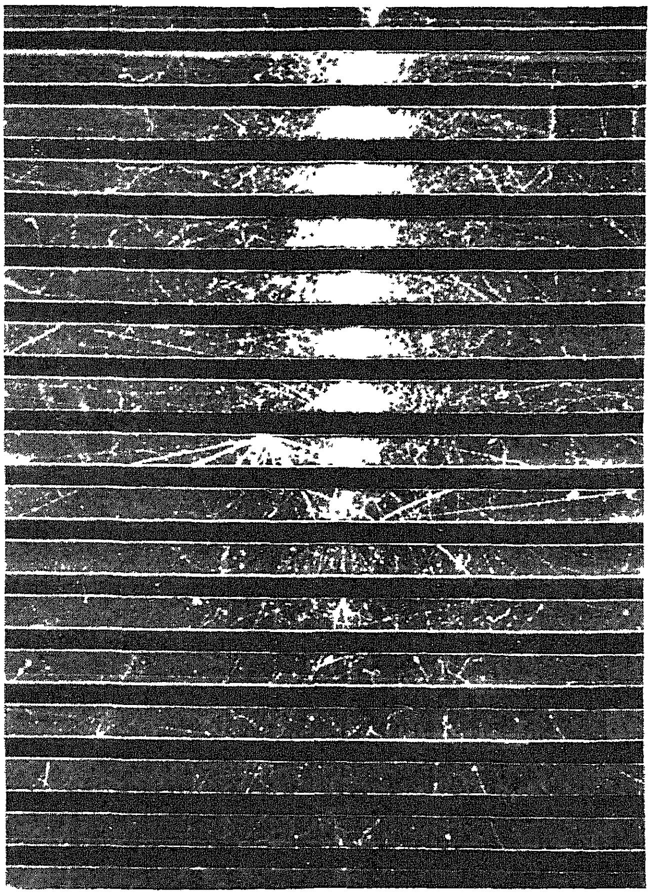
As soon as the presence of highly penetrating mesons at sea level was recognized, scientists began to ask about their origin and whether they occur only singly, or also in pairs and showers The first convincing evidence for a pair was obtained in 1939 by H. J. J. Braddick and G. S. Hensby of Birkbeck College in England. Working in a tunnel 30 meters under the London clay, they photographed the cloud-chamber tracks of a meson pair that passed through 15 centimeters of lead above the chamber and a lead plate two and a half centimeters thick inside the chamber. By 1944 G. D. Rochester at Manchester was able to show photographs of 18 separate showers in which the particles had penetrated 53 centimeters of lead. From these experiments it was clear that high-energy mesons penetrate to sea level as single particles, in pairs, and in showers.

Meanwhile, at the Dublin Institute for Advanced Studies, J. Hamilton, W. Heitler, and H. W. Peng had come up with a theory of origin. According to them, the mesons are produced by the impact of a proton. If the proton hits a single proton or neutron in an elastic collision, the result is a single high-energy meson. If the original proton bangs into a complex nucleus containing several protons and neutrons, the result is a shower of mesons. The Dublin physicists calculate that the proton must carry at least 2,000 mev to initiate a penetrating shower, and the energy may be many times that. The extensive showers discovered by Auger appear to be a combination of cascading electrons and penetrating mesons.

The high energy of the mesons made it difficult to photograph the beginning of a penetrating shower, for invariably the shower started before it entered the recording apparatus. For several years W. B. Fretter has been experimenting at the University of California with different arrangements of cloud chambers, lead plates and Geiger-Muller counters in the effort to set off and photograph penetrating showers inside a cloud chamber. In 1947 he installed a series of eight lead plates horizontally in a large cloud chamber, spacing them an inch apart. Each plate was half an inch thick, so any particle passing through all eight would have to penetrate four inches (more than 10 centimeters) of lead. Fretter figured that some electron showers would be started in the upper stories of this leaden



PENETRATING SHOWER is made up of four particles with sufficient energy to pass through many lead plates. At the top of the shower is a burst of electrons.



LARGE CASCADE SHOWER of electrons commences near the top of the chamber. In earlier stages electrons multiply, but finally they are absorbed by the lead plates.

edifice, but that as the particles penetrated to lower floors, the soft component would be filtered out, and finally that the hard component might collide with nuclei of lead atoms and produce penetrating showers. What he expected happened. He obtained photographs of the fanlike electron showers, of penetrating showers incident from the outside, and of penetrating showers originating in a lead plate. In some instances the penetrating shower started in upper plates, but more frequently in the bottom ones. In 1948, Fretter built a larger cloud chamber with 16 lead plates. During the summer this chamber was taken to Tioga Pass in Yosemite National Park and at that elevation (10,000 feet) it photographs about four showers daily.

The Third Component

In addition to electrons and mesons, the cosmic radiation that reaches sea level includes a third and more massive component: protons and neutrons. All of the neutrons and most of the protons are secondaries, of course, and together they are less numerous than either the electrons or mesons; but many of them carry much energy associated with their heavy masses and cause powerful nuclear effects. Rochester and L. Jánossy found that about a third of the penetrating showers are produced by a non-ionizing radiation, presumably neutrons.

It is because they carry no electric charge that neutrons are non-ionizing, and this makes them difficult to study. But neutrons do have a few preferences, and cosmic-ray explorers have been able to adjust traps to their peculiar behavior For example, whenever a neutron of an energy up to about one mev encounters a boron atom, the nucleus of the atom swallows the neutron and ejects an alpha particle. Serge Korff and E. T. Clark made use of this property in 1941 to study the production of neutrons among the cosmic rays, and since then the method has been increasingly refined and improved, mainly by Korff and his associates at New York University.

The neutron counter is distinguished from the ordinary Geiger-Müller counter by its filling of boron trifluoride gas. This gas within the chamber provides atoms of boron to absorb the neutrons and eject the telltale alpha particles. In order to count the alpha particles, the voltage of the apparatus is adjusted to such a level that the instrument will respond only to the ionization generated by alpha particles. Since each emission of an alpha particle represents the absorption of a neutron, the counting of alpha particles indicates the number of the neutrons.

It is essential to know, however, that the neutrons come from outside the walls of the instrument, and to sort them into slow neutrons and fast neutrons. This information is elicited by an ingenious combination of shields. First the counter is surrounded by a shield of cadmium, and since this metal absorbs only slow neutrons and passes fast ones, the alpha particles released within the chamber give the count for fast neutrons only. Then the cadmium is removed and a shield made of a boron compound is slipped around the counter. Since boron absorbs both slow and fast neutrons of energies up to one mev, no cosmic-ray neutron below that energy level is likely to get through. By comparing the counts obtained under the various conditions of shielding, it is possible to determine the number of neutrons originating in cosmic rays, and to separate them into slow neutrons and fast ones.

Korff and B. Hammermesh devised a mechanism that automatically changes the shields at two-minute intervals, leaving the counter unshielded for an equal period. Using this apparatus at sea level, on mountain elevations, and carried to the stratosphere by sounding balloons, the New York University group has extended its survey of the neutron compo-

nent to heights near 100,000 feet. These readings show that, like the other secondary cosmic rays, neutrons are more numerous in the stratosphere, and diminish in population from there to sea level.

Unsolved Problems

Despite the advances made in sorting out cosmic rays, many questions remain. There are periodic changes in the intensity of the radiation as measured at sea level a daily change, a seasonal change and a 27-day cycle The seasonal change, with winter in the Northern Hemisphere producing two to three per cent more mesons than summer, seems to be related to the solar heating of the atmosphere. Since the exposure to solar heat is greater in summer, the air layers in which mesons are produced are shifted to higher altitudes and are less compact than in winter. The daily change, with the cosmic radiation more intense at night than in the daytime, may also be related to tides in the atmosphere. The 27-day cycle, during which the intensity of the cosmic radiation per 24 hours changes by about one per cent, parallels fairly closely the periods of the Moon's revolutions and the Sun's rotation. But there appears to be no mechanism to relate these phenomena to the cosmic radiation.

However, the Sun does have an influence, for the solar bursts associated with sunspot activity, which sporadically envelop the Earth in magnetic storms, unquestionably affect cosmic-ray intensity. It has been observed repeatedly that two to three days after the outbreak of a magnetic storm, the number of cosmic rays reaching sea level may drop as much as three per cent.

There is another effect which seems to be correlated with occasional magnetic storms, but which operates in just the opposite direction: the number of cosmic rays reaching sea level increases. This effect does not wait two or three days, but manifests itself immediately after the solar outbursts. And the change is large—the rise being up to 15 per cent of normal intensity. There are only three records of such events—they occurred coincidentally with the magnetic storms of February 28, 1942; March 7, 1942; and July 25, 1946 The coincidences were first recognized by Scott E. Forbush of the Carnegie Institution of Washington. Forbush believes that more data are needed before a satisfactory explanation of this extraordinary intensification of cosmic-ray activity can be given, and plans have been made to install one of his instruments in the 11,500-feet-high cosmic-ray laboratory that the University of Chicago maintains at Climax, Colo.

The most fundamental of the unsolved problems of cosmic rays is their origin. Whatever sunspot activity may contribute to enhance the cosmic rainstorm, it is able to account for only a small fraction of the rays. Twenty years ago it was suggested that cosmic rays were by-products of creation and represented energy released by the synthesis of more massive elements out of hydrogen, a process that was presumed to be at work in interstellar space. Another hypothesis posed the annihilation of atoms—the complete conversion of their masses into energy. But the energy carried by the primary cosmic rays is far beyond anything that either of these processes could provide. The annihilation of the heaviest atom known in nature—the complete conversion of the uranium mass into energy—would release only 200,000 mev. As we have seen, there is evidence of primaries carrying several hundred thousand times that energy.

Georges Lemaître of Belgium has suggested that the primaries are the dust from a cosmic explosion that occurred about three billion years ago when the whole mass of the universe was concentrated in a single nucleus. Other cosmologists postulate the influence of powerful electric or magnetic fields, or a combination of both, as the force which endows the cosmic particles with their great energies. Such force fields conceivably may be generated by the rotation of the Milky Way and other galaxies, or more locally by double or individual stars. Last summer Horace W. Babcock of Mount Wilson Observatory reported on a variable star with a changing magnetic field. The field force of this star rises to plus-7,800 gauss, then in a matter of days reverses its polarity to minus-6,500 gauss. Babcock suggests that a fluctuating magnetic field of this magnitude provides a means of accelerating charged particles to the energies observed in cosmic rays.

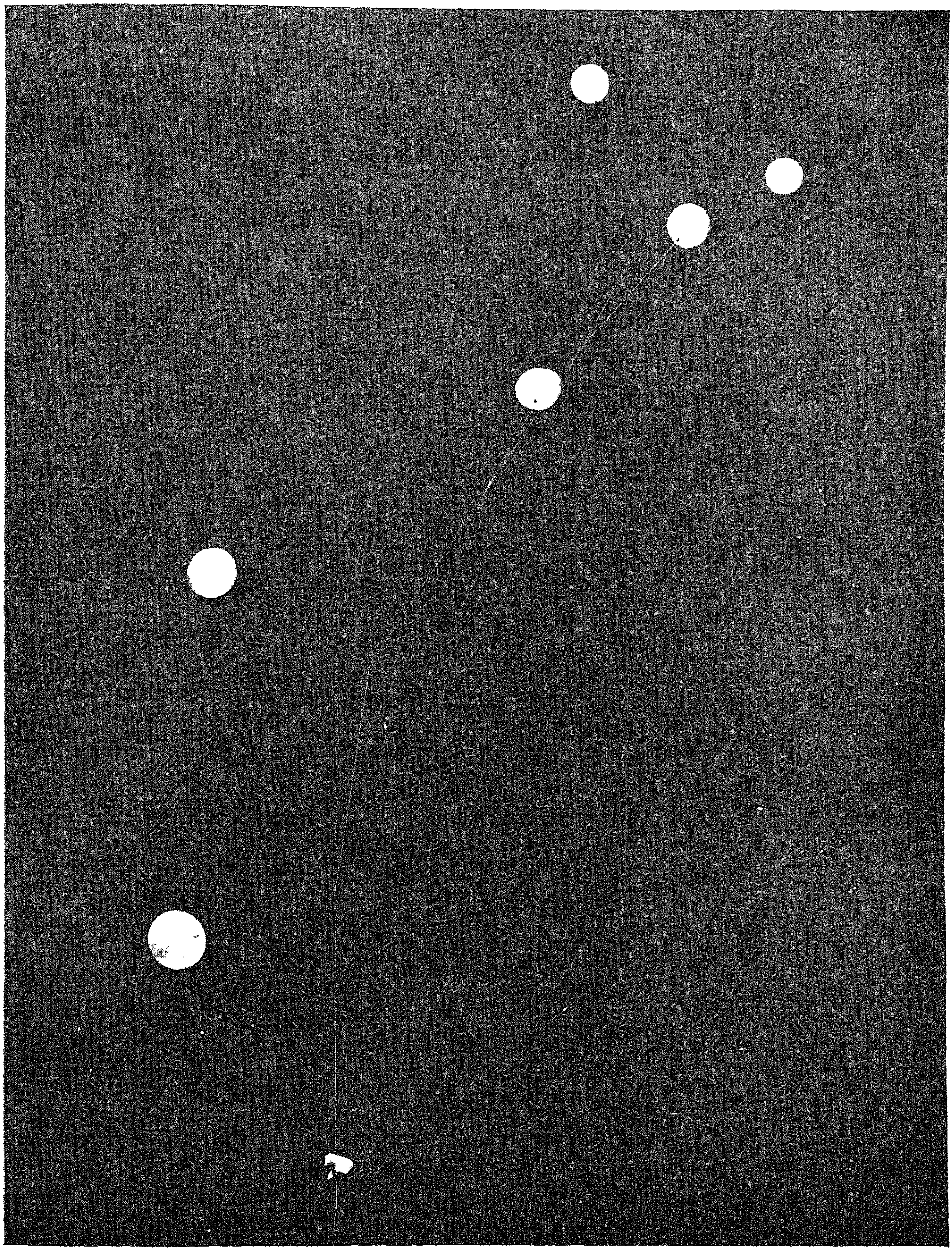
In 1943 the Swedish cosmologist Hannes Alfvén cited evidence for the existence of wandering magnetic fields that move about in the vast emptiness between the stars of the Milky Way. Recently Enrico Fermi of the University of Chicago proposed a new theory of the origin of cosmic rays in which he interprets them as particles accelerated by repeated collisions with these wandering magnetic fields. The whole process seems beautifully logical, with the cosmic-ray particle proceeding from low energy to high, and then to higher and higher, by a sort of chain reaction of collisions. However, Fermi's theory applies only to protons, and, as he has said in his paper communicating the theory to *The Physical Review*, "the chief difficulty is that it fails to explain in a straightforward way the heavy nuclei observed in the primary radiation."

More knowledge is needed, more observations, more year-round measurements of the rays at different latitudes and different altitudes. Balloons will continue to be the principal means of getting instruments to the top of the atmosphere, for they can keep the detectors at a given altitude for hours and possibly for days. But rockets are being made increasingly effective, and undoubtedly will play an important part in the high-altitude research of the next few years.

Most of the mountain observatories are in middle latitudes. In Europe, there is a station on the Jungfrau (3,800 meters), another near Mont Blanc also at 3,800 meters, an outpost in the Italian Alps (3,500 meters), and one at Pic du Midi in the Pyrenees (2,800 meters). In South America, observations have been made in the Bolivian Andes at 5,500 meters, but there is no permanent station there In the U. S., two permanent high-altitude stations for cosmic-ray study are maintained in Colorado, one at Climax by the University of Chicago, the other at Mount Evans (14,256 feet) by a group of six cooperating universities.

For atomic physicists, the pursuit of cosmic rays is today's grand quest. No other problem is absorbing the efforts of so many top experimenters and theorists. Some, like Carl Anderson of California and C. M. G. Lattes of Brazil, are interested in the rays as tools for prying into the structure of atomic nuclei. Others are seeking to elucidate the rays themselves. Last summer a whole constellation of these researchers was camped at various sites on the slopes and near the summit of Mount Evans, 60 miles west of Denver, and perhaps nowhere else in the world was there such a concentration of cosmic-ray detectors and detectives. The Inter-University High-Altitude Laboratory, which occupies a two-room building near the summit, is directed by a board made up of representatives of the Universities of Chicago, Cornell, Denver, New York, Princeton and the Massachusetts Institute of Technology, with Byron E Cohn of Denver as chairman. The Laboratory also maintains research equipment and living quarters part way down the slope at Echo Lake (10,600 feet). All six participating universities and several guest research institutions had teams at work in this area last summer. When snow began to isolate the summit in mid-September, the researchers withdrew to Echo Lake, and winter and spring operations are being conducted there by groups from Cornell, Denver, M. I. T. and Princeton. Photographic plates were left in the summit laboratory to record whatever cosmic rays come their way By the middle of June it is expected that the road will be sufficiently free of snow for observers to get back and see what their ion traps picked up in the long months of isolation.

George W. Gray is author of The Great Ravelled Knot *and other articles that have appeared in this magazine.*



BALLOONS bear aloft a lightweight cloud chamber to record cosmic-ray phenomena at altitudes between 50,000 and 100,000 feet. This flight was launched last summer by Carl D. Anderson from the campus of the University of Denver. Many balloons are used so that when some burst at high altitude, the others will gently lower the apparatus. Rockets also have carried detectors to high altitudes, but obviously for short periods.

THE ANCESTORS OF MAMMALS

In the Permian and Triassic Periods lived the therapsids and the ictidosaurs, a curious group of reptiles with many mammalian characteristics

by Edwin H. Colbert

IT IS difficult to see much in common between a modern reptile, such as a crocodile, and a modern mammal, such as a dog Anatomically and physiologically they seem to be about as far apart as possible for four-footed animals. But if we go back in geologic time we find a close connection between some of the early mammals and certain reptiles. Improbable as it may seem, the fossil record shows that the earliest mammals were descended from reptilian ancestors.

It was somewhat more than a century ago that the bones of mammal-like reptiles were first discovered in South Africa by Andrew Geddes Bain, a well-known fossil collector of the period. Bain's specimens were noted and described by the great English anatomist and paleontologist, Sir Richard Owen. The significance of Bain's findings was overlooked for decades.

Charles Darwin's disciple Thomas Huxley suggested that the mammals had arisen from amphibians, a conclusion to which he was led by his studies in comparative anatomy. But in the years between about 1870 and 1884 Owen and the brilliant U. S. paleontologist Edward Drinker Cope, after studying certain fossil reptiles from South Africa, independently reached another conclusion which has been strengthened with every passing year—namely that the ancestry of the mammals is to be found in these fossil reptiles of the Permian and Triassic Periods, some 150 to 230 million years ago.

THE physiological, reproductive and anatomical differences between living reptiles and mammals are readily apparent. First, the reptiles are "cold-blooded" animals in which the internal body temperature varies more or less directly with the temperature of their environment; mammals are "warm-blooded," with a fairly constant body heat and an outer covering of hair to insulate them. The reptiles, as a result of their lack of temperature control, are for the most part sluggish, by comparison with the active mammals. Most of the reptiles lay eggs from which the young are hatched, though some retain the eggs within the body of the female so that the young are born alive In most mammals, the embryo develops and is nourished within the uterus of the mother. And the mammals of course are distinguished by the property from which they derive their name they suckle their young.

Many of the anatomical differences between modern reptiles and mammals are reflections of physiological or reproductive differences. The reptiles are typified by a relatively small and simple brain, whereas mammals have a large brain. Modern reptiles have a single bony joint at the base of the skull, the occipital condyle, to articulate the head with the backbone, mammals have two condyles. The lower jaw in reptiles consists of several elements, one of which, the articular bone, works against the quadrate bone of the skull to form the articulation between skull and jaw. In mammals there is a single jawbone, the dentary, which articulates directly with the squamosal bone of the skull. Reptiles have a single bone in the middle ear, mammals have a chain of three. The teeth of a reptile are generally pretty much alike, and they are renewed by many "generations," so that a replacement is on hand for any tooth that may drop out. The teeth of mammals are differentiated into incisors, canines, premolars and molars, and a mammal is limited to two sets—the "milk" teeth and the later permanent teeth.

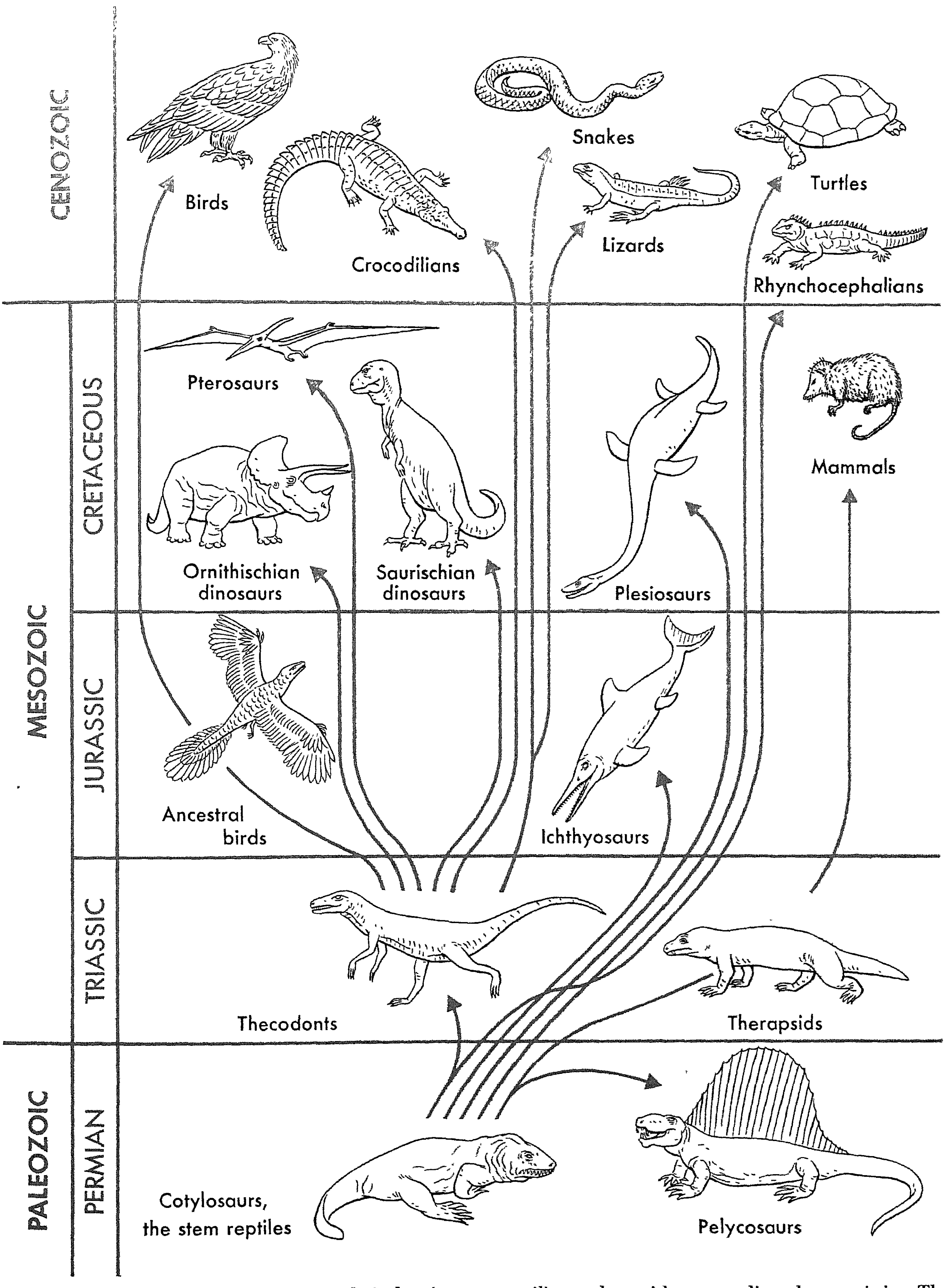
There are also important differences in the rest of the skeleton. The vertebrae of a reptile are fairly uniform, whereas in a mammal they are strongly differentiated in the neck, thorax and lumbar regions. A reptile's long bones usually can continue to grow throughout the life of the animal; a mammal, on the other hand, has separate "epiphyses" at the ends of the bones which become fused with the bones as the animal reaches maturity and prevent further growth. In reptiles the number of bones in the fingers and toes varies, while in mammals they are limited to two bones in the thumb and big toe and three bones in each of the other fingers and toes.

Because of these many differences, the early anatomists failed to see the relationship between mammals and reptiles. But with the discovery of many bones of mammal-like reptiles in South Africa, notably by the physician-paleontologist Robert Broom, a multitude of likenesses appeared Although by far the greatest number and variety of these reptiles has been excavated from South Africa, by now they have also been found in many parts of the world, including North and South America, Russia, England and western China It is therefore apparent that during the last stages of the Paleozoic Era and the first stages of the Mesozoic they were spread over almost all the earth.

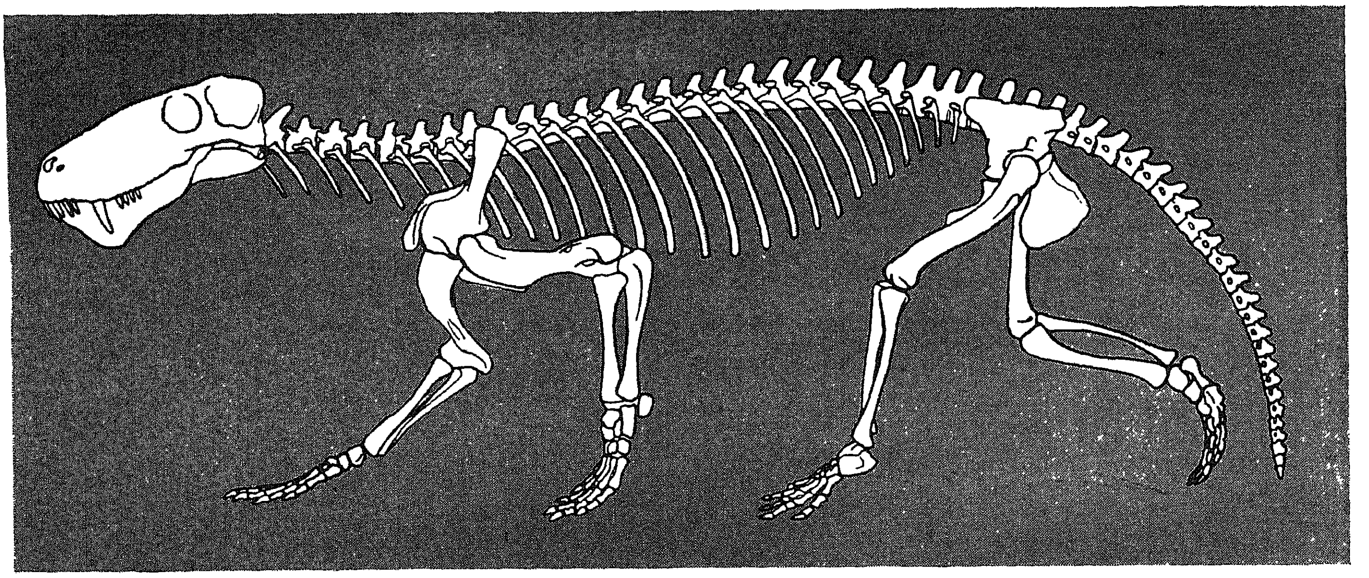
The reptiles from which the mammals are believed to have come belong to two orders, known as the therapsids and the ictidosaurs. Of particular interest among the therapsids is the suborder called the theriodonts, so named from their "beast"-like or mammal-like teeth. An especially important genus of theriodont is *Cynognathus* (meaning dog-jaw).

TO ANYONE familiar with modern reptiles, *Cynognathus* seems most unreptilian. In life this animal must have been very different in appearance and in actions from the reptiles of today. Even the fossilized bones show this, for in *Cynognathus* many anatomical characters bridge the structural gap between reptile and mammal

Cynognathus was a rather large animal with a long, doglike skull, as big as the skull of a wolf Evidently it was carnivorous, for its skull is armed with sharp, strong teeth well adapted to seizing and tearing its prey. These teeth, quite unlike those of the carnivorous crocodile, are not evenly spaced and uniform but rather are separated into differentiated groups like the teeth of many mammals. They must surely have functioned like mammals' teeth. In the front of the jaws are small, conical incisor teeth for nipping or biting. Behind the incisors there is a gap, followed by a single, large, daggerlike canine in each of the upper and lower jaws. Like the canine in present-day wolves or foxes, it must have been the great, slashing knife that formed the principal weapon of the animal. Behind it are the cheek teeth, which in mammals are known as the pre-



MAMMAL-LIKE REPTILES occupy a relatively minor position in the entire reptilian line of descent. At lower right are the therapsids, with the ictidosaurs one of the reptilian orders with mammalian characteristics. The early mammal which is shown in the Cretaceous Period (*near top*) is rather similar to the present-day opossum.



LYCAENOPS is a typical species among the mammal-like reptiles. It is one of the theriodonts, meaning that it had beastlike teeth. The theriodonts are a suborder of the therapsids. One of the distinguishing features of *Lycaenops*, and other mammal-like reptiles, is a pair of long teeth used as slashing instruments. This restoration was made by the author and artist John C. Germann at New York's American Museum of Natural History.

molars and molars. In *Cynognathus*, as in the mammals, these teeth are complex, with several cusps forming the crown of each tooth. Evidently they were useful for cutting food into small pieces, so that it could be quickly assimilated by the digestive system. This is indeed a contrast to the living reptiles, which bolt their food and then digest it slowly.

There are various other mammal-like characters in the skull of *Cynognathus*. For instance, as a corollary to its perfected dentition, this animal, like the mammals, had a secondary bony palate separating the respiratory tract from the alimentary passage. This obviously added to the efficiency and speed of eating, which were important to a relatively active animal. Again, in *Cynognathus* as in the mammals, there are two condyles joining the skull to the first vertebra of the backbone.

Various mammal-like characters appear in the skeleton of *Cynognathus* behind the skull. Thus there is a considerable degree of specialization of the vertebrae: those in the neck are different from the rib-bearing trunk vertebrae, and one can see the beginnings of a ribless lumbar region, as in the mammals. The shoulder blade has a strong spine along its front edge—something quite new for the reptiles, and a forerunner of the spine that is so distinctive of the mammalian shoulder blade. In the pelvic girdle the ilium is elongated, and much of this elongation is forward, so that the bone begins to develop a shape prophetic of the mammalian ilium. The limbs and the feet are in certain respects rather mammal-like. Evidently *Cynognathus* had a somewhat mammal-like posture, with the body carried well above the ground and the feet pulled in toward the midline to give strong support and increase the efficiency of walking.

Yet in spite of all these advances, *Cynognathus* is distinctly a reptile, and it retains many of its ancient reptilian features. Thus it has a full complement of reptile bones in the skull, and to a large degree in the skeleton as well. There is little of the loss and coalescence of bones so typical of mammalian structure. The lower jaw is formed of several bones instead of a single one, and the skull is hinged to the lower jaw in the typical reptilian arrangement. The finger and toe bones are entirely reptilian.

For all that, *Cynognathus* represents a great forward step in evolutionary development. Moreover, certain other theriodont reptiles related to *Cynognathus* show advances in characters where *Cynognathus* was conservative. For instance, a theriodont known as *Bauria*, which in many respects is less mammal-like than *Cynognathus*, has the same number of bones in its toes as a mammal has. Thus while no one theriodont reptile approaches completely the mammalian type of structure, the theriodonts as a group clearly exhibit a trend in that direction.

THE approach toward the mammals is carried even further in the ictidosaurs, of which we unfortunately know all too little. The ictidosaurs possess to an even more advanced degree the various mammal-like characters that are distinctive of the theriodonts; in addition, they show trends toward the mammals in certain characters that are still thoroughly reptilian in the theriodonts. For instance, the ictidosaurs have lost some of the skull bones characteristic of the theriodonts and have a very much more mammalian skull pattern. They show a further advance in the bony secondary palate. The ictidosaurs also have a greatly enlarged dentary bone in the lower jaw—a step toward the single jawbone of the mammals. But they still have other bones in the lower jaw and a typically reptilian hinge between skull and jaw.

Discoveries in two localities on opposite sides of the earth in recent years have extended greatly our knowledge of the ictidosaurs. In China, Dr. Chung Chien Young has described ictidosaur skulls and bones that he unearthed in Yunnan; in England Walter Kuhne, by the most painstaking methods, has also obtained skulls and parts of skeletons of these very important predecessors of the mammals. These ictidosaurs bear many structural resemblances to the platypus of Australia, the most primitive of living mammals.

At what stage in their evolution did these mammal-like reptiles cross the threshold into full mammalian status? We can assume that the reptile ceased to be a reptile and became a mammal when it had established a constant body temperature and an insulating coat of hair, and when reproduction had reached an advanced stage of development, especially when the female had begun to lactate and suckle its young. Unfortunately we can obtain no direct evidence on these changes, for temperature controls, hair, mammary glands and other soft parts of the anatomy are not preserved as fossils.

Considering only the bones, we can say that the evolving animal had reached a mammalian stage when it achieved the combination of structural features already indicated as characteristic of mammals, that is, a full differentiation of the vertebrae, a fused pelvis, perfected feet, epiphyses on the long bones, a double

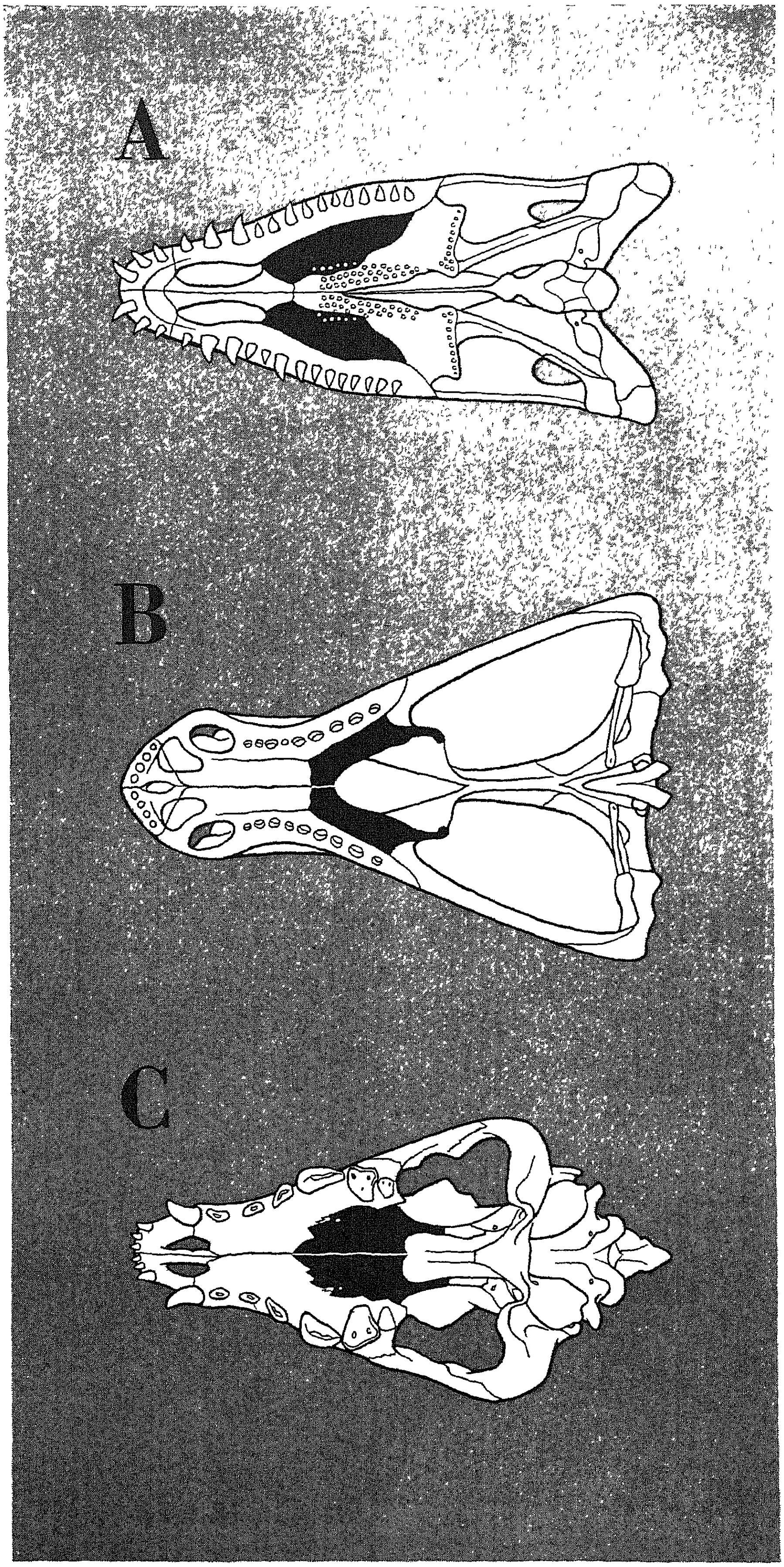
occipital condyle at the base of the skull, a perfected secondary palate, a chain of three small bones in the middle ear, and a single lower jawbone articulating with the skull. Of these features, the last is perhaps the most significant.

In the mammal-like reptiles, there was a progressive reduction of the quadrate and articular bones which formed the reptilian articulation between skull and jaw; in the ictidosaurs these elements were very small indeed. Now from a synthesis of embryological and paleontological evidence we know that in the final transition from reptile to mammal, there was a remarkable transformation in these bones. As the reptile became more nearly a mammal, the two bones finally abandoned their functions as articulating elements between the skull and the jaw, and entered the middle ear. The quadrate became the mammalian incus bone, the articular became the mammalian malleus, and together with the stapes the three bones formed the chain of ear ossicles that is characteristic of the mammals. At the same time a new joint was formed between the squamosal of the skull and the dentary, the only bone left in the lower jaw.

None of the ictidosaurs had quite attained this stage of evolution, and so by definition they can still be regarded as reptiles. Yet at that point the distinction between reptile and mammal had become so narrow that the line of demarcation between them must be based, perhaps arbitrarily, on this difference between a single ear ossicle and three ear ossicles. Though seemingly insignificant, the difference is so constant that it serves admirably as a reference point at which to draw the very fine line between reptiles and mammals.

THE first mammals probably looked very much like the mammal-like reptiles that were their immediate ancestors. It was in the Triassic Period of earth history that the change from reptile to mammal was made, and from the succeeding Jurassic Period on, we can see mammals sharing the earth with reptiles. The Triassic Period was still early in the Mesozoic Era, the great age of dinosaurs. For a long time, geologically speaking, the early mammals were destined to live in a world full of reptiles. It was a lush, tropical world, in which the giant reptiles were supreme and the mammals relatively insignificant. But as the conditions on the land changed, the earth became more suitable for mammals than for reptiles. By the time the mammals became dominant on the earth, their reptilian ancestors had long been extinct.

Edwin H. Colbert is a paleontologist at the American Museum of Natural History. He is also professor of vertebrate paleontology at Columbia University.



DEVELOPMENT of secondary palate (*black*) illustrates evolutionary position of the mammal-like reptiles. Early mammal-like reptile *Dimetrodon* (A) had tiny palate, with nostrils opening into mouth. Later mammal-like reptile *Cynognathus* (B) had closed nasal passage. Dog has full palate.

THE X-RAY MICROSCOPE

It does not exist, but the fundamental problem has been solved. When a practical model has been built, it will open some doors closed to electrons and light

by Paul Kirkpatrick

EVERY microscopist knows the sharpening of fine detail which becomes apparent in the material he is viewing when a reddish light is replaced by the shorter waves of blue. Probably he has also wished that he could see by the still shorter waves of ultraviolet light, which would afford him a fuller measure of the same helpful treatment. Photographic films do have ultraviolet vision, and there are special microscopes that make full use of it. Such instruments are more costly and less convenient than conventional microscopes, but these disadvantages may well be overlooked when resolution of fine structures is the essential problem.

Long waves simply cannot produce the sharp and faithful images of small bodies that are possible with short waves. This is an inevasible law of nature. Of course, no wavelength will produce good images without good lenses, or whatever one uses for lenses, but assuming perfection in these parts the ultimate advantage in the matter of resolving power lies with the shorter waves. This is why the electron microscope, in spite of its expense and its demanding techniques, was able to make an immediate and distinguished place for itself in competition with conventional methods which had been perfected by generations of development. Yet electrons, though they achieve much finer resolution than does light, are weak in penetrating power, and so their seeing ability is limited to very thin specimens.

An ideal agent for microscopy would be X-rays, which combine a wide range of penetrating powers with very short wavelengths—from 100 to 10,000 times shorter than those of light. Thus the possibility of an X-ray microscope has been an alluring subject of speculation ever since the short-wave nature of X-rays was first surmised. But the difficulties have seemed too formidable. In one of his earliest experiments, Wilhelm Konrad Rontgen, the discoverer of X-rays, tried to focus them with lenses of glass and of hard rubber but found both ineffective. With the statement, "It is obvious that X-rays cannot be concentrated by lenses," Rontgen seems to have abandoned his attempts. His pessimism has been shared by a long generation of his successors who came to know far more about X-rays than the discoverer had lived to learn. Although hope was never entirely abandoned, the status of the X-ray microscope became mainly that of a legendary instrument famous chiefly for the supposed impossibility of its existence.

For a quarter of a century it has been quite clear why lenses will not work with X-rays. To focus the rays, a lens must refract them, and refraction depends on the production of an orderly effect on the electrons in the lens. The electric field of the X-ray wave reverses itself so frequently that the relatively sluggish electrons in a lens of any material cannot follow, and are scarcely disturbed The wave is almost without effect upon matter, and *vice versa* The radiation passes with very little refraction. To make the best of a bad situation we might place a large number of lenses in series and gain a cooperative effect which would increase the refraction. With the ordinary kind of X-rays a train of 100 lenses might have a combined focal length as short as 100 meters. Perhaps the best material for these lenses would be beryllium, a substance relatively transparent to X-rays. Even so, this weak lens system because of its great thickness would not be very transparent, and it obviously would be exceedingly cumbersome.

These discouraging considerations turned the writer's thoughts toward the possibility of doing the trick with mirrors. In telescopes, projectors and microscopes working with ordinary light, the designer has the choice of refraction or reflection systems. He often finds reason for preferring the latter. So we have found it to be in the production of X-ray images. We are not considering here the well-known type of reflection that takes place when crystals are illuminated by X-rays It is doubtful that crystal mirrors of precise figure could be produced, and in any case crystal reflections are weak. A more promising type of X-ray reflection, requiring only polished surfaces, has been available since its discovery by the physicist Arthur Holly Compton in 1922

Compton's reflection is of the total type It is similar to the total reflection of ordinary light that occurs within the prisms of field glasses or at the surface of water when the light comes from under the surface. A difference is that whereas light undergoes total reflection only when striking the boundary of its medium from inside the medium, X-rays are totally reflected only when they strike a material medium from outside. This contrasting behavior obtains because X-ray vibrations are of higher frequency than those natural to the electrons of matter, while light frequencies are lower.

Whether with X-rays or with light, the reflection takes place only within a restricted range of angles of incidence. In the case of X-rays this range is most inconveniently narrow. Only the rays that strike at a very small angle, *i.e.*, those that lie nearly parallel to the surface of the mirror, are destined for reflection. The critical angle below which reflectible rays lie is larger for some X-rays and some mirrors than for others; but even in

the favorable case of the X-rays of the longest wavelengths striking a mirror of high density, the critical angle does not often exceed one degree.

This narrow gateway to reflection has heretofore seemed to offer so little promise that a recent Patent Office search turned up not one patented invention relating to total X-ray reflection. Nevertheless, it turns out that optical images may be formed by curved mirrors even under these strict limitations We consider first spherical mirrors, not that they are necessarily ideal but because they are easy to obtain and because their properties are familiar

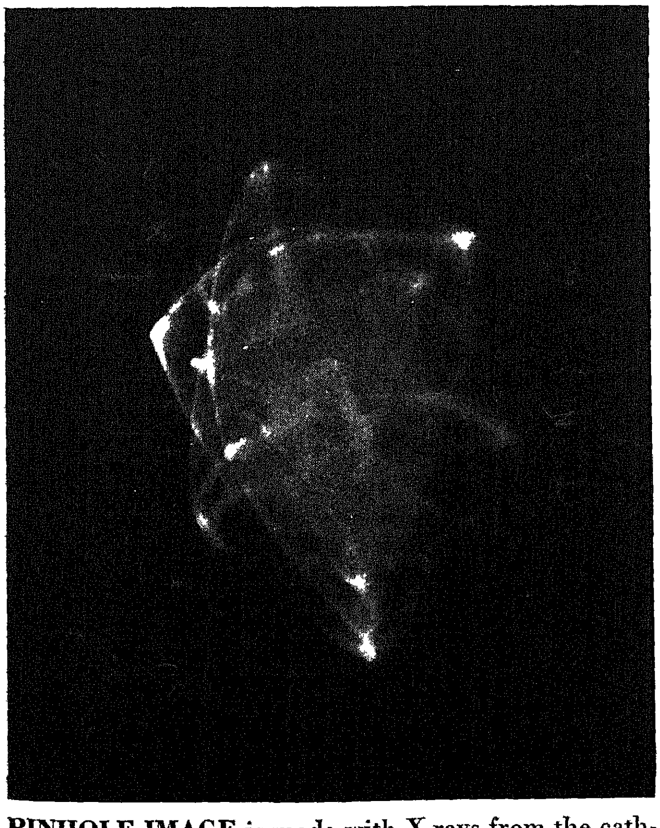
If radiation from a sufficiently distant point source strikes a concave, spherical mirror within the critical angle, the image formed is not a point but a line—the well-known phenomenon of astigmatism (*illustrated in the middle drawing on page 47*) The line focuses at a perfectly definite position governed by a focal length which depends in a known manner upon the curvature of the mirror and the angle of incidence. A mirror of this kind is, of course, quite unable to produce a true image of an object, but its astigmatism may be corrected by another mirror of contrasting properties, as an astigmatic human eye is corrected by the supplementary action of an equally astigmatic spectacle lens.

Correcting the astigmatism of X-rays is achieved by mounting two concave mirrors close together but with their faces at right angles to each other (*bottom drawing on page 47*). Rays from a point object, reflecting in sequence from the two mirrors, converge to a point image, and therefore an extended object yields an extended, two-dimensional image. This process is at the heart of the design for an X-ray microscope.

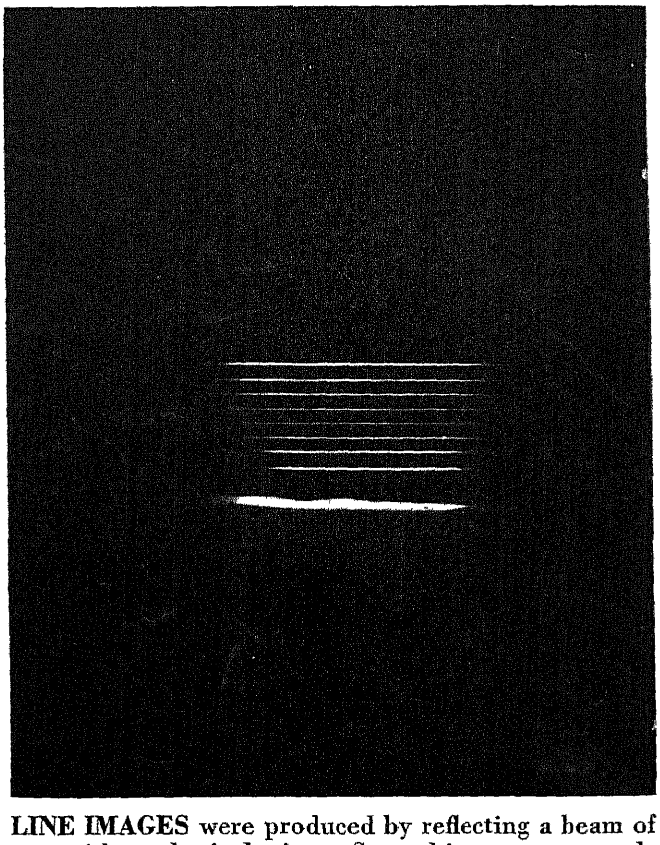
If the X-ray microscope is to become a useful reality, it must produce not merely an image but a good image. X-ray images are subject to many of the common optical aberrations and limitations Since the images are not formed by refraction, there is no chromatic aberration But the spherical aberration is strong. Spherical aberration may be reduced by using a very small opening, which narrows the rays to a small section of the mirror In the system just described, spherical aberration is prevented from ruining the images only by the extremely narrow apertures with which we have thus far worked—about $f1{,}000$, which is much tinier than the smallest opening ($f64$) in a conventional camera. A small aperture is undesirable, however, for it is antagonistic to speed of photographic exposure and to resolving power. Unless resolving power is conserved, half the advantage of X-rays is lost, so spherical aberration must be combatted by some weapon other than the aperture stop.

The fundamental way to get rid of spherical aberration is to abandon spheres. The geometrical form which truly reflects rays from point object to point image is not the sphere but the ellipsoid, *i e.*, the shape approximately represented by an egg or a cigar. One might suppose that a single ellipsoidal mirror—for example, a portion of the inside surface of a hollow, cigar-shaped reflector—would be a better image-forming device than the odd combination of two mirrors at right angles. The suggestion turns out to be disappointing; such a mirror, if it could be made, would produce at one focus of the ellipsoid a good image of a point radiation source situated at the other focus, but the field of useful vision would be very small: all points of the object except the one right on the focus would be very badly imaged. The useful field of the two-mirror combination is thousands of times larger than that of a single ellipsoid

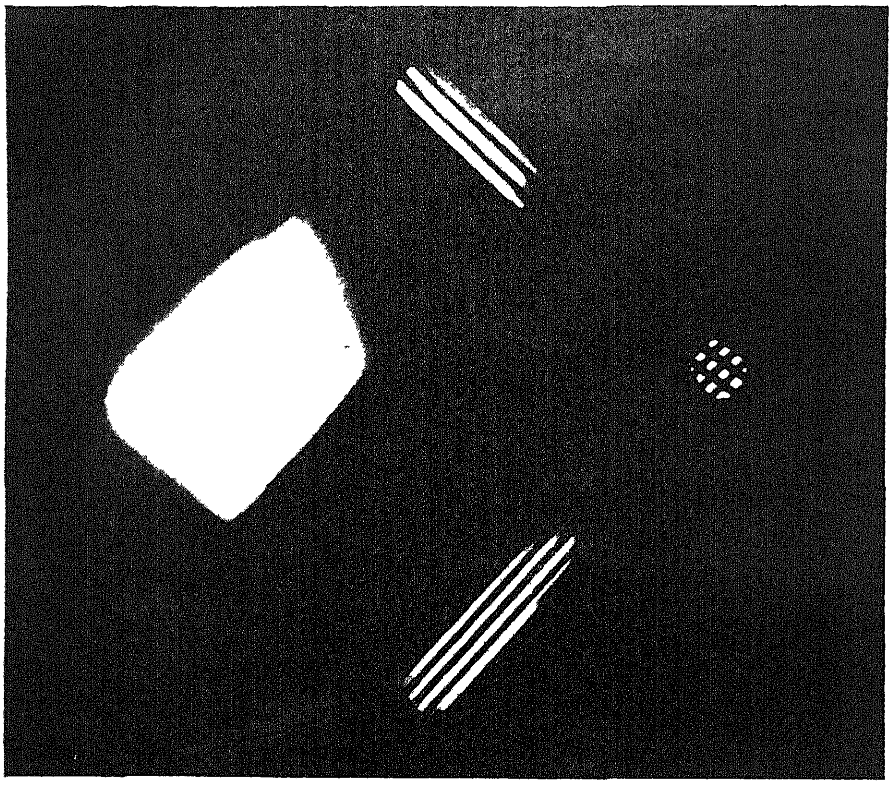
To use the elliptical focusing principle in a two-mirror combination, we require mirrors curved in the shape of a selected portion of an ellipse along the direction of the rays The curvature in the crosswise direction is unimportant We have found it possible to produce such aberration-free mirrors by the controlled condensation of metallic vapors



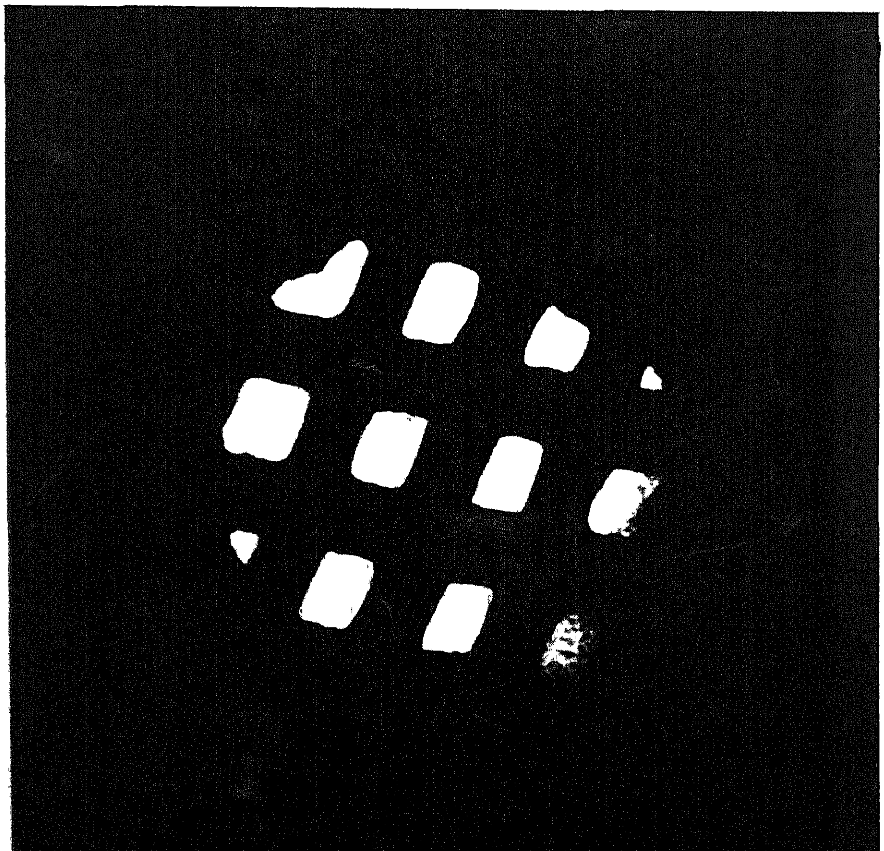
PINHOLE IMAGE is made with X-rays from the cathode of a deep therapy X-ray tube. The image is a crude copy of the structure formed by the cathode itself.



LINE IMAGES were produced by reflecting a beam of rays with a spherical mirror. Several images were made by exposing a photographic plate at various distances.



CORRECTED IMAGE is produced by two spherical mirrors arranged in the manner shown at bottom of opposite page. Object was a screen with 350 meshes per inch. Image is at the right. At top and bottom are astigmatic images of each mirror. Spot at left is caused by direct radiation.



ENLARGEMENT OF IMAGE that appears at the right in the photograph above demonstrates fundamentally good quality. The definition of the image is limited only by the grain of the photographic plate. Further corrections, however, may be achieved by the use of three spherical mirrors in series.

upon glass surfaces This is an adaptation of the method developed by the physicist John Strong for converting spherical telescope mirrors into parabolic mirrors. The glass surface to be built up is mounted in a vacuum with its face downward, over a little crucible in which silver or other metal may be melted and evaporated to dryness Between the crucible and the glass a carefully designed brass interceptor moves in a precisely controlled manner which allows the evaporating metal atoms to pass in desired amounts to the areas where they are needed. Silver, which vaporizes readily, is used in building up the surface, and it is built up to a layer as thick as a wavelength of visible light on some areas of the glass. The finish coat is a uniform layer of platinum, applied not for appearance or protection but to widen the angular range within which total reflection is possible, for, as was indicated earlier, the maximum angle of reflection depends upon the material of the mirror surface

Thus far our program of research has been directed toward the solution of basic problems of design and construction, and there have been no attempts to realize high magnifications or resolving powers A theoretical calculation indicates that an X-ray mirror system using the full aperture permitted by the critical angle would be just able to resolve object points 70 Angstrom units apart (one Angstrom = 1/100,000,000 centimeter). This resolving power is about 25 times greater than that attainable by the finest visible-light microscope. It is an odd fact that the limit is independent of the X-ray wavelength—apparently a contradiction of the optical rule that the shorter the wavelength the better the resolution. The reason is that the improvement of resolving power which should be gained by a decrease of wavelength is nullified by the change of critical angle which inevitably accompanies the change in wavelength.

WHETHER an X-ray microscope would achieve a gain in magnification is of less consequence than its resolving power. The importance of magnification in the observation of small things is popularly overestimated. It is a simple matter to blow up a small picture by photographic enlargement, or to project it upon a screen and thereby magnify it thousands of times. Such magnification serves no purpose beyond the point at which the finest authentic detail of the picture is rendered plainly visible. Further magnification does not sharpen an essentially blurry focus or refine a coarse resolution. The important thing is to get the detail into the picture in the first place, whether the picture be large or small. This requires an adequate resolving power in the optical system and a fine grain at the photographic surface.

The operating rule with the X-ray microscope will be to use only enough primary magnification to ensure that photographic grain size is not the factor limiting the detail recorded upon the film. Images thus recorded may then be stepped up to convenient size by photographic enlargement. The alternative plan of doing the whole thing by X-ray magnification would be a slower process, since exposure time must be increased proportionally with the square of the linear magnification.

X-rays, like electrons, should have a clear superiority over visible or ultraviolet light in the matter of resolving power, but at present it seems unlikely that X-ray microscopes will ever equal the magnificent resolutions already attained by electron microscopes. In comparing X-rays with electrons we should take note of an important difference in the manner of their penetration through matter. An X-ray beam will be weakened in such a passage, but the surviving portion will be as truly on its course as if it had come through a vacuum. An electron beam, on the other hand, not only is weakened by the removal of some of its particles, but most of those which survive will have been drawn off their original courses by small amounts. This is one reason why the air must be removed from the paths to be traversed by electrons in the electron microscope, leaving the specimens under examination mounted naked in the vacuum. Such exposure, which is damaging to some biological materials, is not required with X-ray microscopes. In them, perishable specimens may be surrounded by light gases and water vapor. An X-ray microscope would also be much simpler in construction and operation than is the electron microscope.

THE wide range of penetrative powers provided by the X-ray spectrum suggests the application of X-ray microscopic methods to metals and minerals too dense for electron penetration. In current practice such materials are studied by microradiography down to a limit set by photographic grain size. With X-ray magnification available, this limit may be pushed on down.

The progress of science is the progress permitted by its instruments. Any extension of the powers of an instrument allows its users to move upon new problems. Detailed prediction is doubtful business, but, as history is repetitive, the addition of a new radiation to microscopy should open new doors.

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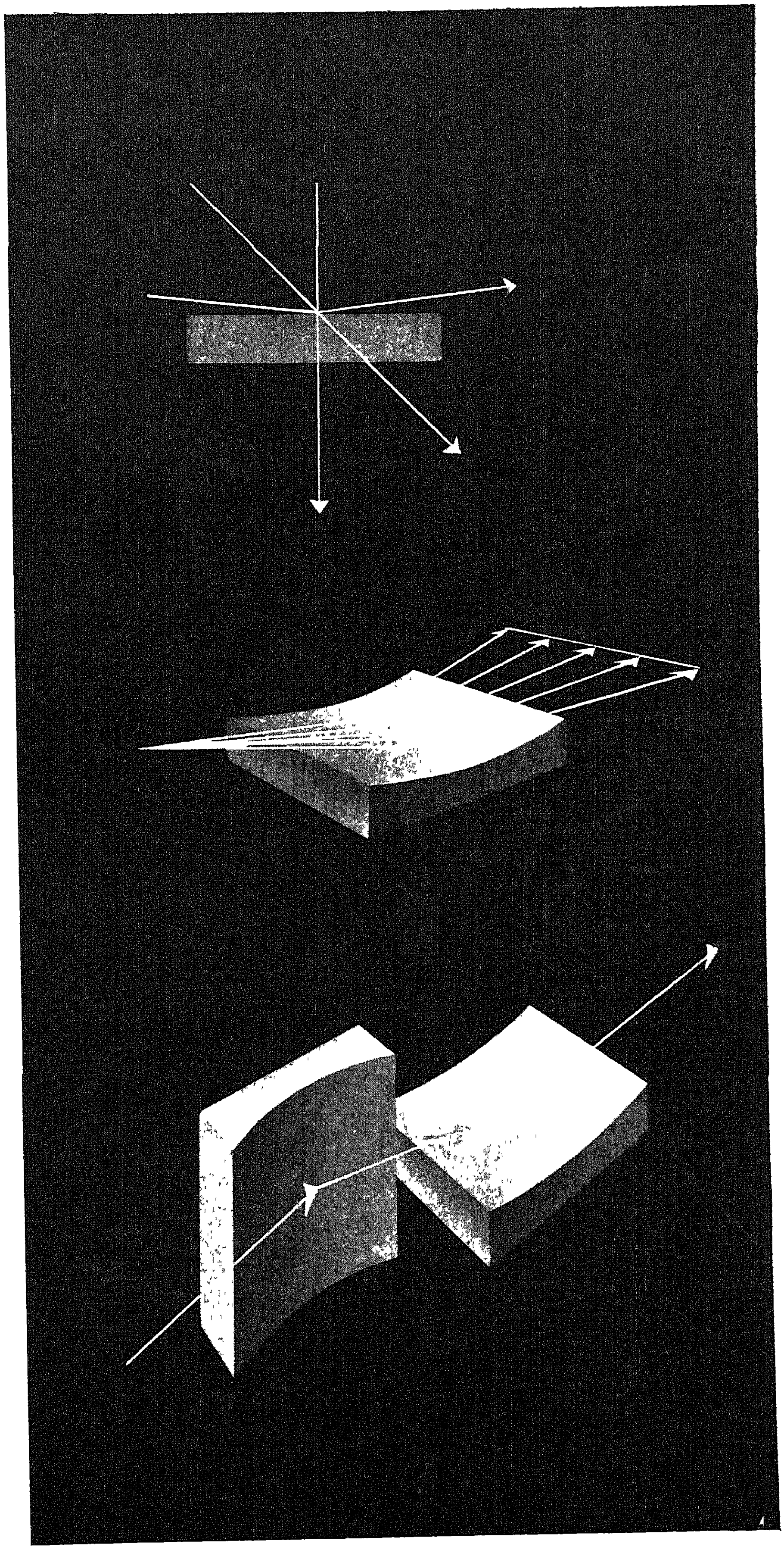

BASIC PRINCIPLE of X-ray microscopy is that a mirror will reflect rays only at a very shallow angle (*top*). Rays from a point source may be focused by a spherical mirror, but the image is astigmatic (*center*). Point image of a point source may be produced by two spherical mirrors (*bottom*).

CHEMICAL WARFARE AMONG THE PLANTS

Cooperation and competition are familiar institutions of the plant kingdom. Some plants make use of a form of antisocial behavior to inhibit their competitors

by James Bonner

PLANTS, like animals, do not live alone. Just as every animal's environment includes other animals, so a plant is affected by other plants in its community. There is such a thing as a sociology of plants, and a very considerable amount of attention has been given to various phases of that study. It is known that members of the plant kingdom not only compete among themselves for food, light and water but often engage in more subtle forms of warfare or cooperation. This article will deal with a remarkable phenomenon in plant relations that has only recently come to light: the fact that some plants possess chemical weapons with which they attack their neighbors.

The explanation of this phenomenon requires some preliminary consideration of the facts of plant ecology, *i.e.*, the interrelations among plants and their environment. If we look at a plant society, we see that it is almost always made up not only of individuals of the same species but of a number of species, all growing together in more or less intimacy. It is easy enough to understand why plants of the same species should settle in the same place: they have similar requirements and all can thrive on, or at least tolerate, the physical environment of that particular habitat. But what are the factors that determine which species of plants may dwell together?

One significant clue lies in the fact that certain groups of species are likely to be found together in many sites where similar conditions prevail. So constant are these societies that it is possible to classify the groups and to name them as particular communities and associations, just as taxonomists name individual species of plants or animals. On the other hand, there are species that are never found together in the same association, even though members of these species may range widely over the same general geographic region. The citizens of the plant world, one may say, are segregated into exclusive associations which get along congenially in their own groups but do not mix with foreigners.

Obviously the most important selective factors are climate and the physical surroundings. The species that grow in association thrive on similar conditions of temperature, light, water and soil. This is particularly evident in the cases of plants that grow under unusual conditions—in bogs, in high meadows, in salty sinks, on seacoasts, in arid, rocky deserts. Undoubtedly many plant associations, perhaps all, are influenced in their species composition by this factor of site selection by the species that are best adapted to that site. A great deal of the work done in plant ecology has involved trying to find out just what the physical factors are that condition a particular plant association.

AN individual plant influences the well-being of the other individuals in its association in various ways, of which the best understood is the competition for some factor essential to growth, such as light, water, or mineral elements. This might be called economic conflict. Thus limitations in soil nutrients or in soil moisture may restrict the total number of individuals that can live on a given area. Or again a tree, when it becomes established in brush vegetation, as it grows taller may rob the shrubs of light to such an extent that the latter may no longer be able to survive. These economic factors of competition vary considerably in importance, depending on whether the different species involved tend to be equal or disparate in height, on whether their roots grow through the same layer of soil or exploit different soil layers, and so on. It is probably an axiom of plant sociology that a stable plant community tends to be made up of species whose individuals provide the least amount of economic competition to one another.

The method of interaction among individual plants with which we are here concerned is not, however, based on competition, at least not in the same sense. It has to do with the production by a particular species of chemical substances that are given off to the soil and influence the growth and welfare of other species. The plants that war upon one another in this way would not necessarily be in conflict so far as food or other requirements are concerned. They appear, however, to be inherently antagonistic.

In the field of microbiology this kind of phenomenon has been known for some time. We are well acquainted with a certain microscopic plant that produces poisonous substances: the fungus *Penicillium notatum*, which yields penicillin, a chemical that is highly toxic to a wide variety of other organisms. In 1932, four years after Alexander Fleming discovered penicillin, the U. S. botanist Richard Weindling found that a soil fungus named *Glyocladium* produced a substance, glyotoxin, which was toxic to the growth of other organisms, including other fungi. Scores of such antisocial chemicals have now been isolated from a wide variety of microorganisms (although only a few have all the properties needed to make them effective therapeutically in higher animals as are penicillin and streptomycin).

That higher plants also possess this property has long been suspected. Augustin de Candolle, the great Swiss botanist of the early 19th century, recorded that thistles appeared to inhibit the growth of oats. He suggested that this interaction might be due to specific chemical inhibitors. The first experiments specifically designed to test this hypothesis were carried out in England by S. C. Pickering and the Duke of Bedford in the early years of this century. In one type of experiment they grew apple trees in tubs moistened with water that had previously leached through pots containing growing grasses. They showed that the grasses appeared to produce in the water a principle that inhibited the growth of apple trees. In a

PLANT COMMUNITY is a group of species that live in harmony to the exclusion of other species. The example given here is a maple-beech forest of the eastern U. S. The tree at left is a sugar maple. The larger trees at right are beech. Several other plants commonly dwell with these two species. The smaller trees at right are dogwood. On the floor of the maple-beech forest are found witch hazel (*left and center*) and the dogtooth violet.

PLANT COMPETITION is illustrated by the example of a pine forest in which hardwood trees have gained a foothold. The tall trees in this drawing are pine; the small saplings below are gum, maple, oak and hickory.

END OF COMPETITION shown in the drawing at left is a forest of oak and hickory. Pines no longer grow in significant numbers. This type of forest competition usually begins when pines are weakened by enemies.

BLACK WALNUT (*Juglans nigra*) may produce a chemical inimical to other species. Juglone, a compound found in its roots and leaves, has been investigated.

WORMWOOD (*Artemisia absinthium*) produces a chemical called absinthin that discourages growth of certain species. Absinthin is washed onto the soil by rain.

series of brilliant investigations carried out by Oswald Schreiner and his colleagues in the U. S. Department of Agriculture, four different substances toxic to plant growth were isolated from various soils. In none of these early investigations, however, was there complete proof that a particular species growing in nature or in the field is inhibited by an identifiable substance produced by a second species. The evidence which led to this conclusion has been obtained only in recent years.

Perhaps the most detailed observation made was that by the German H. Bode and the Belgian G. L. Funke in the years 1939 to 1943. Bode, who worked in a garden of pharmaceutical plants, observed that along the two sides of a row of plants of the wormwood, *Artemisia absinthium*, individuals of other species grew very poorly or were killed outright. The inhibitory influence of the row of wormwood extended for upward of a meter in each direction. This growth-depressing effect could not be attributed to competition of the *Artemisia* with other plants, for other shrub species of size and habit closely comparable to wormwood exerted no such effects. Bode showed that the action of the wormwood on other plants was due to a chemical compound, absinthin, which is produced in glandular hairs on the surface of the *Artemisia* leaves. The compound is washed off onto the adjacent soil by rain, and the toxicity of the soil is constantly renewed as recurring rains bring fresh supplies of the toxic compound to it. The effect of absinthin is not the same on all species of plants. A few appear to be resistant to it. When *Artemisia absinthium* is grown in the field, Funke discovered, only these resistant species appear in the same patch, the other weed species usually found in such sites are suppressed.

ANOTHER antisocial chemical is produced by leaves of the brittlebush, *Encelia farinosa,* which inhabits the low hot deserts of the U. S. Southwest. F. W. Went of the California Institute of Technology, studying the flora of this region, found that most of the species of perennial shrubs growing there harbor a vigorous coterie of annuals around them, no doubt in part at least because they provide shade and an accumulation of organic matter for the lesser plants. The brittlebush, however, is a conspicuous exception. The area under and around a brittlebush is in general barren of other plants except in certain special circumstances. Because the absence of other plants did not appear to be due to simple competition effects, fallen leaves of the brittlebush were scraped from the ground under the bush and taken to a laboratory for study. When they were placed as a mulch over sand in pots in which tomatoes or other species were growing, it was found that the brittlebush leaves, even in small quantities, caused severe retardation of growth, or even the death, of the test plant.

The toxic action of *Encelia* leaves, like that of *Absinthium,* is highly specific. It has little effect on the brittlebush itself, on sunflowers, or on barley; but it has a pronounced influence on certain other plants, notably, as has been mentioned, the tomato. On chemical fractionation, the *Encelia* leaves yielded a toxic compound which, isolated in crystalline form, was found to be a new chemical substance, 3-acetyl-6-methoxy benzaldehyde. This compound, when synthesized in the laboratory, had a toxic activity identical with that of the natural material. Experiments have shown that the fallen leaves of the brittlebush retain their toxicity for a year or more in the absence of rain, and that the toxic material is leached out into the soil by water. Annuals usually associated with shrubs, such as *Rafinesquia,* are highly susceptible to the brittlebush toxic substance. It may therefore be concluded that the lack of growth of annuals in association with *Encelia* under natural conditions may be due to the production by brittlebush of this toxic substance. An exceptional situation occurs, however, in certain mountainous areas where *Encelia* grows on steep slopes that are subject to occasional torrential runoff. There the ground under the plant is free of the mulch of fallen leaves, and it is not uncommon to find individuals of sever-

GUAYULE (*Parthenium argentatum*), the rubber-bearing shrub of the U.S. Southwest, manufactures a chemical which inhibits the seedlings of same species.

BRITTLEBUSH (*Encelia farinosa*), a shrub living in the deserts of the Southwest, secretes 3-acetyl-6-methoxy benzaldehyde to prevent the growth of nearby plants.

al other species growing in association with the shrub.

It has been known for many years that the black walnut (*Juglans nigra*) exerts a detrimental effect on the growth of surrounding plants of many species, and it has often been suggested that this may be due to a chemical substance produced by the tree. Everett Davis, working in West Virginia, sought to determine whether the injurious effects produced by the black walnut derived from juglone, a compound found in the foliage and roots of the plant. He showed that juglone is toxic to tomato and alfalfa plants. It has not been proved, however, that juglone is in fact the means by which the black walnut injures other plants under natural conditions. This case remains to be worked out in detail, and it is of interest to do so because of the prevalence of black walnut poisoning of crops in the East and Southwest.

Chemical interaction is not restricted to plants of different species. We know that in some instances a plant may produce a compound which is inhibitory to plants of its own species. Such a plant is the guayule, *Parthenium argentatum*, a rubber-bearing shrub of the southwest desert. When this plant is grown under laboratory conditions, the roots give off a substance that is toxic to seedlings of the same species. The inhibitor was isolated in pure form and shown to be cinnamic acid. This substance has a powerful effect: less than one part in 200,000 parts of soil is sufficient to bring about a significant depression of seedling growth.

Why should a plant produce a compound highly toxic to its own species and much less toxic to other species? An answer to this question may perhaps be found in the way in which shrubby species are distributed under desert conditions. Normally in such an environment the individuals of a given species are widely and uniformly spaced, as though to share the scant supplies of water and nutrients. Seedlings of guayule are rarely found under a mature guayule plant—a situation common to a wide range of desert shrubs. Even when guayule seedlings are transplanted into the neighborhood of a mature guayule plant they show poor survival and little growth. It can be shown by experiment that this failure is directly related to the inhibitor produced by the mature plant. The explanation may be that the mature guayule plant produces its inhibitor to prevent the establishment of young competitors for water and food.

The chemical interaction between plants is not always hostile. There are plants that produce substances which promote the growth of other plants instead of inhibiting it. Certain leguminous plants excrete nitrogenous compounds which may be taken up and used by associated non-leguminous species. F. W. Went has shown that in the tropical rain forest of Java each species of forest tree has its own particular species of epiphytes, higher plants whose seeds germinate and grow high up on the trunk of the host. This specificity of epiphyte for host tree may be a reflection of the effects of particular compounds from the tree on the germination and growth of the seeds of the epiphyte species.

It is clear that further and more detailed investigations are necessary in order to discover the exact limits of chemical interaction among higher plants. It appears that the production of substances inhibitory to other plants may be very widespread in the plant world. In a survey of native woody species of one section of eastern California alone, it was found that the leaves of approximately half of the species collected contained principles toxic to the growth of one selected test plant.

Fundamentally, of course, the chemical interactions among plants must have something to do with the factor of competition, which is undoubtedly of the most general and pervasive significance in plant relations. Thus chemical warfare and cooperation are merely one phase of the larger complex of interactions which determine the sociology of the plant community.

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1905 PORTRAIT of Einstein was made in the year of his greatest productivity. While he worked as a clerk in the Swiss patent office, he made his great contribution to the quantum theory and published a paper entitled "On the Electrodynamics of Moving Bodies." It was this that set forth the special theory of relativity.

THE INFLUENCE OF ALBERT EINSTEIN

This month he is 70. It is an appropriate time to reflect on his achievements and to consider the present state of the work he began in 1905

by Banesh Hoffmann

ALBERT EINSTEIN, whose 70th birthday this month is being noted throughout the civilized world, occupies a position unique among scientists He has become a legend in his own lifetime. The public adulation of him is so great that he dare not list his telephone number in the directory. When he delivers one of his rare lectures at the Institute for Advanced Study in Princeton, no notice of it may be posted on a bulletin board, the news must be passed around among his colleagues by word of mouth, lest it leak out and the lecture hall be overrun by reporters and curiosity seekers.

It is relativity, of course, that has made Einstein's name a household word, and there can be no question that this one revolutionary achievement has been and will continue to be the distinction that sets him apart. The theory of relativity has a monumental quality that places its author among the truly great scientists of all time, in the select company of Isaac Newton and Archimedes. With its fascinating paradoxes and spectacular successes it fired the imagination of the public—and until recently all but obscured Einstein's many other contributions to science.

In the perspective of half a century, these contributions have grown in importance Considering recent developments in physics, any estimate of his influence must recognize not only his quality as a great independent innovator but also his activities in advancing the fruitful progress of physical theory.

Einstein has lived in an era of unprecedented scientific change, much of which was generated by his own discoveries. Yet science was ripe for great upheavals even before his arrival. The seeds of scientific unrest that led to the theory of relativity had already been planted when Einstein was a boy. And the fundamental tenets of physical science were destined to be disrupted even more dramatically by the quantum theory, which had its birth in 1900. To the quantum theory Einstein himself made vital contributions Indeed, the Nobel prize was awarded to him in 1921 not specifically for his controversial theory of relativity but "for his merits on behalf of theoretical physics, and in particular for his discovery of the law of the photoelectric effect."

Although Einstein is commonly thought of as an ivory-tower scholar, he has always had a happy knack for influencing the course of events, and a remarkable instinct for detecting the needle of truth in a haystack of speculation. This is perhaps best shown in his quantum work of 1905. He was then an unknown scientist, not even associated with a university. Five years earlier Max Planck had suggested that matter must absorb and give off energy not in a continuous flow but in minute bundles, or quanta. Nowadays, with the quantum so firmly established, even a professional physicist finds difficulty in recapturing the sense of outrage that such an idea must have provoked at the time. The idea was outright heresy. It was as if a scientist had said, in all seriousness, that something could be in two places at once (Indeed, the development of the theory ultimately did imply that.)

PLANCK himself viewed his idea with misgiving, and at first it made no headway. The young Einstein, however, dared to take it seriously. With cogent arguments he showed that the energy that was given off in bundles must somehow continue to exist in bundles—bundles of light, which we now call photons. Since centuries of research, culminating in the electromagnetic equations of James Clerk Maxwell, had pointed indisputably to the fact that light was a wave, this idea of bundles or particles of light was surely nonsense. Yet somehow it had to be sensible, for Einstein showed that it was able to explain phenomena that the wave theory could not encompass, notably the photoelectric effect, in which the energy of electrons knocked out of a metallic surface by light shining on it depended not on the intensity but on the wavelength of the light.

Einstein's idea of particles of light marked a turning point in the history of the quantum. Though fundamentally simple, it was the product of extraordinary boldness and scientific insight. For the idea of particles of light was beset by enormous difficulties. Perhaps light did consist of particles, as Einstein said. But it certainly consisted of waves, as he was acutely aware. This paradox plagued scientists for many a year before it was resolved by Werner Heisenberg and Niels Bohr in terms of the modern quantum theory.

In the early 1920s the French theoretical physicist Louis de Broglie put forward the weird idea that electrons and other particles of matter were accompanied by curious sorts of waves. For years he developed his ideas without awakening any echo of response from other scientists. The French physicist P. Langevin was the first to see that they might have merit. And one day Einstein happened to come across them. Struck by their boldness, and by an inner plausibility beneath their outward appearance of fantasy, he espoused them in the scientific press. The response was spectacular. Einstein's recommendations brought the ideas of de Broglie to the attention of the brilliant Austrian physicist Erwin Schrödinger. Schrödinger forthwith transformed them into the successful quantum theory of wave mechanics, which now forms a central part of modern atomic physics and which proved to be substantially the same as the apparently different theory by which Heisenberg and Bohr resolved the particle-wave dilemma.

Einstein's achievements in that single year of 1905 are breathtaking. While busy earning his living in the Swiss patent office, he found time not only for his epoch-making work on the quantum but also for important contributions to the theory of the Brownian movement—the incessant agitation of microscopic particles caused by molecular bombardment. In the same year he published a paper,

bearing the unprepossessing title "On the Electrodynamics of Moving Bodies," in which he set forth the special theory of relativity. And, to cap it all, in a second paper on relativity in that same year he made his celebrated deduction of the equivalence of mass and energy. $E=mc^2$.

If the quantum idea required boldness, what shall we say of the theory of relativity? Where the idea of particles of light challenged a mere theory, relativity challenged a universal and ingrained conception of time. We see nothing out of the way in the statement that Joe DiMaggio hit a home run in one baseball game at the same moment that Johnny Mize hit one in another. It does not occur to us that this implies that the phrase "the same moment" has meaning. It seems ridiculous to raise the question.

Yet Einstein successfully challenged this attitude. Reasoning from precise experimental data, including the celebrated experiment of Michelson and Morley on the speed of light through the "ether," he showed that we must give up, at whatever emotional cost, our belief that "the same moment" has a definite meaning. Events at different places that occur at the same moment for one observer definitely do not occur at the same moment for another observer moving relative to the first. Simultaneity is not absolute It depends on the observer Time is relative.

EINSTEIN went on to prove that space, too, must be relative, that no object can move faster than light, that mass increases with speed and, in brief, that all of theoretical physics, based as it was on erroneous ideas of space and time, must be reconstructed.

Newton's theory of gravitation, which had reigned unchallenged for more than 200 years, clearly did not fit the stringent requirements of relativity. Yet the problem of replacing it was so difficult that Einstein took 10 years to find the solution. And to do so he had to construct a general theory of relativity, beside which the special theory of 1905 appeared almost an incident.

The German mathematician Herman Minkowski had discovered in 1908 a striking relationship between equations of the special theory of relativity and equations used by geometers of multidimensional spaces. From this relationship he deduced that space and time are fused together into a single four-dimensional entity: space-time.

The space-time that Minkowski found in the special theory of relativity was flat. Einstein, guided by speculations on such simple situations as the operation of gravity with relation to a moving elevator, concluded that gravitation must be equivalent to a curvature of space-time, the idea of a force of gravitation being irrelevant. If gravitation was associated with a curvature of space-time, that alone was a reason why bodies under the influence of gravitational "attraction" followed curved paths

The general theory of relativity is more than an imposing intellectual structure It has a grandeur that is also esthetic. From the idea of curved space-time the equations governing gravitation flowed with such inevitability and logical economy as to make the general theory a masterpiece of art as well as science.

Only a deep faith could have sustained Einstein's courage through the years of lonely effort before experiment showed his labors had not been in vain. He once made a remark to me that throws a revealing light on his methods. When estimating the value of a possible physical idea, he said, he asked himself whether it seemed so natural that he would have made the universe that way had he been God. If the idea did not possess this esthetic quality, he mistrusted it.

In the general theory of relativity, gravitation was envisaged as only a minor puckering or roughness in an otherwise smooth space-time. In 1917 Einstein found reasons for supposing that the four-dimensional universe taken as a whole might be roughly cylindrical in shape. Not even Einstein could visualize a four-dimensional cylinder, but it could be conceived in mathematical terms. With this idea he inaugurated the subject of relativistic cosmology.

The Dutch astronomer W. de Sitter then suggested a different shape that goes by the name of pseudo-spherical. His theory predicted that distant bodies would appear to recede from us, a prediction tentatively borne out by the sketchy astronomical data then available. Thus prompted, the astronomers made further measurements, and found that the most distant nebulae did indeed appear to be receding at altogether staggering rates. Unfortunately de Sitter's model applied only to a theoretically empty universe. Einstein's model, on the other hand, did pertain to a universe inhabited by matter and radiation, but it predicted no recession of bodies of matter from one another.

To obtain a recession in a universe that was not empty, the Belgian cosmologist Abbé Lemaître in 1927 developed his theory of the expanding universe, which supposes that the universe exploded long ago and that its fragments are still flying apart—a theory which has recently been applied by George Gamow and R. A. Alpher to account for the origin of elements and their relative abundances in the universe (SCIENTIFIC AMERICAN, July, 1948).

Meanwhile Hermann Weyl of Germany had introduced the idea of a unified field theory. If what was once called gravitational force could be considered as curvature, he argued, why should not electromagnetic forces also have a geometrical basis? Gravitational curvature affects directions: for instance, an airplane flying half way round the earth would end up pointing in the direction opposite to the one in which it started. Weyl therefore suggested that electromagnetic forces might be connected with an analogous effect upon lengths, much as if the airplane ended up not only with a different direction but also a different size Because this plausible and ingenious idea actually yielded the same equations as those of Maxwell governing the electromagnetic field, it excited considerable attention But Einstein, while greatly admiring it, found it unacceptable because it violated physical principles; he proved that the Weyl theory implied that atoms would emit light of all frequencies, whereas actually they produce sharp spectral lines indicating radiation only at specific frequencies.

The German mathematician Th. Kaluza later showed that Einstein's gravitational equations could be made to yield Maxwell's electromagnetic equations by expanding them to fit a special five-dimensional setting. What the fifth dimension might be, Kaluza could not say. Despite this, the result was so remarkable that Einstein and many others have since worked on the idea. And in 1930 the American geometer Oswald Veblen discovered that the so-called fifth dimension was not a fifth dimension at all but a familiar mathematical quantity used by geometers in studying what they call the projective geometry of four dimensions.

THE EQUATIONS of Maxwell and Einstein were thus successfully brought together. But the problem of the structure of matter and radiation could not be solved in terms of the equations as they stood. If it was ever to be solved along the lines of a field theory—which was by no means certain—modifications of some sort would have to be introduced. Accordingly the search was renewed with more ambitious aims.

For more than 25 years Einstein has devoted his main scientific energies to this problem. While the quantum theorists are moving ahead in close touch with the latest details of nuclear experiment, Einstein is attempting to gain an insight into the nature of matter and radiation by abstract reasoning from a few general assumptions. In this he is following the heroic method that proved so successful —in his hands—in the formulation of the theory of relativity. Unfortunately there are many possible approaches, and since each requires a year or more of intensive computation, progress has been heartbreakingly slow.

What was once the broad stream of relativistic research has shrunk to a slender rivulet. The quantum theory, so frail in 1905 when Einstein first befriended it, now dominates physics. It has developed a stature comparable to that of the theory

of relativity, and has proved to be even more iconoclastic. It has corroded concepts such as determinism and causality that once seemed indispensable to any rational science. It has elevated chance to a commanding position in scientific theory. And it has upset our powers of visualization by replacing the former conception of a particle by a hybrid monstrosity such that when we speak of its precise position we are forbidden to speak of its motion, while when we think of its exact motion we may not regard it as possessing position at all.

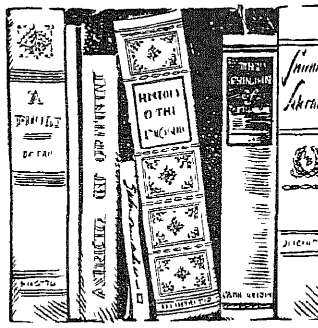
While developing his theory of relativity, Einstein continued to contribute valuable ideas to the burgeoning quantum theory. He applied it with signal success to the theory of specific heats. He propounded the quantum law of photochemical equivalents that goes by his name. He gave a new deduction of Planck's radiation formula, introducing important concepts regarding the process of radiation. And he applied de Broglie's ideas to the theory of gases when those ideas were still unproved.

NEVERTHELESS, Einstein is out of sympathy with the modern form of the quantum theory. Most theoretical physicists, on the other hand, doubt that the problem Einstein has set himself is aimed in the right direction, since it apparently avoids the quantum. But it must be remembered that in 1905 most theorists were doubting the very idea of the quantum. Einstein's present views may not be fashionable, and the chances of a successful outcome of his work may appear slim. Yet he has always been a lonely thinker, and physicists will not easily forget that Einstein is the man who, from abstract considerations of space and time alone, was able to deduce the equivalence of mass and energy without needing to know the detailed structure of either. The quantum theorists themselves are encountering formidable difficulties of a fundamental nature. The time seems ripe for a further synthesis through an imaginative stroke of insight by an Einstein.

The importance of Einstein's scientific ideas does not reside merely in their great success. Equally powerful has been their psychological effect. At a crucial epoch in the history of science Einstein demonstrated that long-accepted ideas were not in any way sacred. And it was this more than anything else that freed the imaginations of men like Bohr and de Broglie and inspired their daring triumphs in the realm of the quantum. Wherever we look, the physics of the 20th century bears the indelible imprint of Einstein's genius.

Banesh Hoffmann is associate professor of mathematics at Queens College and author of The Strange Story of the Quantum.

IN 1939 Einstein was photographed at home at Princeton, N. J. There he gives an occasional lecture at the Institute for Advanced Study. Today his activity is limited by his convalescense from a recent surgical operation.



BOOKS

Arthur Koestler's "Insight and Outlook": the novelist formulates a philosophy complete with circuit diagrams

by James R. Newman

INSIGHT AND OUTLOOK, by Arthur Koestler. The Macmillan Company ($5.00).

THE subtitle of Arthur Koestler's latest work is "An Inquiry Into the Common Foundations of Science, Art and Social Ethics." It is also described as a "book on the psychology of the higher mental functions." The publisher tells us that Koestler spent five years "reading widely in the fields of biology, neurology and psychology" in preparing himself to "do for philosophy what Einstein attempted for physics in his 'unitary field theory.'" I am therefore somewhat appalled at the task of reducing this epic achievement to the humdrum prose of the reviewer; but if I am to say anything intelligible about what Koestler refers to as "our theory," there is no alternative but to be bold.

His jumping-off-place is a new theory of the comic. It is not, in truth, entirely new, as Koestler himself points out, since he borrows freely from Henri Bergson (*Le Rire*), Sigmund Freud (*Wit and Its Relation to the Unconscious*) and from a number of their predecessors. However, the special blend of literary-medical-philosophical-psychoanalytical-biological lingo and the mental-circuit diagrams in the book are more or less Koestler's own products; and the ambitious extension of conclusions derived from an analysis of humor to all other forms of mental behavior bears his very own mark.

Koestler starts his long journey to the heartland of insight with the aid of a number of stories quoted from Freud, Bergson and others. They serve to introduce his "discovery" that the "essence of the comic is the bisociation of two operative fields in a junctional concept which is a member of both."

The formidable terms used by Koestler are perhaps best illustrated by means of two stories:

(1) "M. DuPont, an elderly notary of Clermont-Ferrand, has for years suffered from the annoying habits of his clerk Jules. Returning home unexpectedly from a journey, he finds Jules in bed with his wife. M. DuPont surveys the scene with a mournful eye and says: 'That is enough, Jules! Once more and you are fired.'"

(2) "A dignitary of Monte Carlo is much admired for the not less than 36 medals which he wears on his breast. Somebody asks him by what heroic deeds he earned them. 'That's simple,' he says, 'I got a medal for my faithful service to the prince, I put it on a number at the roulette table and the number came up.'"

The "intellectual geometry" of these droll stories is, according to Koestler, quite simple. It consists in something like the diagrams on the opposite page, which mean something like this.

As the tale is told there are "two unrelated association trains" which suddenly collide with each other at a given point. Each train is perfectly "logical" (*i.e.*, has its "operative field") and under normal circumstances "the stream of consciousness would follow either one branch or the other, for the two belong to different systems or planes of mental organization." At the collision of these two trains, however, a new concept is born which "serves two masters at the same time ... it is *bisociated* with two independent and mutually exclusive fields."

As Koestler's blueprints plainly prove, at the point where the two association trains collide, the joke (a new bisociated concept) flashes into being and the auditor laughs. In M. DuPont's tale one thought train relates to his business dealings with the unsatisfactory Jules, and the other train to the familiar complex consisting in cuckold, wife, paramour, and discovery *flagrante delictu*. The expectation of a violent climax is suddenly "debunked" with a phrase from the employer-employee relationship.

Each train of a comic event may carry a different "emotional charge" (*e.g.*, malicious, sexual, scatological), but it is the process of combining habitually incompatible fields of thought that results in the sudden release of tension and the explosion of laughter—assuming, indeed, that there is laughter.

TO EXPLAIN how attention is focused on any one field, how the mind is disciplined to concentration, Koestler proposes the concept of the "selective operator." The operator defines its field in the sense that it is a selective law, a "rule for manipulating ideas and their verbal symbols." Operators may be simple and explicit, as in a parlor game, for example, where the participants are to write down within a time limit all the towns they can remember beginning with the letter L. The class of all L towns—London, Lisbon, Lvov, etc.—constitutes the operative field, and the L-rule is the selective operator. Operators may also be exceedingly complex and/or implicit, just as the operative field may consist, among others, in a code, a pattern of behavior, a chessboard and chessmen, a branch of mathematics, a musical or plastic art, a literary form.

Such is the technical apparatus used by Koestler in exploring provinces other than the comic. Bisociation is the "characteristic feature of any original creative process whether in art or in discovery," since every fresh synthesis entails the combination or union of elements in previously separate areas of thought. Even the diagrams devised to exhibit the mechanics of the comic are, according to Koestler, applicable to the processes of higher creativeness. The separate fields joined in the creative synthesis are represented by "planes," and the little straggling arrows represent separate trains of thought association.

As for the concept of "emotive charge," it, too, like the "intellectual geometry" of the comic, has validity and significance in other spheres. In a humorous context the "common denominator" of the charge is "usually a very faint impulse of aggression or defense manifested as malice, derision, self-assertion, or merely as an absence of sympathy with the victim of the joke—a 'momentary anesthesia of the heart,' as Bergson puts it."

"The passion of laughter," said the English philosopher Thomas Hobbes, "is nothing else but sudden glory arising from a sudden conception of some eminency in ourselves, by comparison with the infirmity of others, or with our own formerly." From this starting point, Koestler develops the argument that the production of comic and certain other effects depends upon the dominance of this aggressive component or "self-assertive" tendency over the opposite tendency of "sympathetic identification" or "self-transcendence."

The integrative or self-transcending tendency, manifested with a certain simple purity in grief, is, in every human activity, in conflict with that of self-assertion. Every true act of creation, in whatever field, requires an expansion of

the "range of awareness beyond the limits of self, or, conversely, of being aware of the self as part of a higher functional whole." The work of art, the generous impulse, the scientific discovery; the feeling of tenderness and protectiveness, the longing for martyrdom; the processes of "identification," "projection," "introjection," "transference," "sympathy" and "empathy"; the "oceanic" feeling, the mysticism and the wisdom of the East, the striving of the spike-sitting Hindu and the Hollywood Hindu toward "nonattachment"; the struggle to achieve, to improve and to extend social wholes—each of these, says Koestler, is evidence of the self-transcending urge

WHAT are the biological foundations of these tendencies? Koestler rests his interpretation on the "twin phenomena of differentiation and integration, which under conditions of stress become polarized into the conflicting tendencies of self-assertive and integrative behavior." A corollary function, of almost equal importance, is that of "regenerative equilibrium": an organism unable to cope with its environmental problems, or the conflict between its opposing tendencies, regresses to a lower biological, social or psychological level in order to start afresh by way of *"reculer pour mieux sauter"* (to retreat so as to get a better start for the jump).

Organized social wholes, Koestler contends, follow this biological pattern, not "morphologically," to be sure, but "functionally." Social organizations simply evince the integrative tendency on a higher level, though it is essential to realize that in the social field contemporary organizations correspond to fairly primitive organizations in the biological field. Sociologically we must be closer to the grub, say, than to anything quite so elaborate as a donkey.

Social wholes tend to grow weaker as they are isolated, as they grow too big and become unwieldy, as separate parts strive for autonomy, as communications are obstructed. Each of these circumstances contributes to self-assertiveness at the expense of the integrative self-transcending power. Within any given society, among individuals at different age levels, there are further illustrations of bipolarity and conflict. In the process of "maturation" a child's sense of oneness with the environment wanes and the self-assertive tendencies increase. In Western societies of course these tendencies are encouraged by the sacred slogans of competition and so on.

This, in Koestler's opinion, suffices to explain the crisis in present civilization. It is not, as Freud supposed, the suppression of man's destructive or death instinct that ails us. It is rather that we witness the "atrophy of the integrative tendencies in the social whole." Civilization is in the condition of a neurotic patient. To put civilization on a couch is difficult, and one may doubt that there is a therapist qualified to tackle the job of reintegration. (One may, I assume, dispense with any reference to the succor which might come from a supernatural power.)

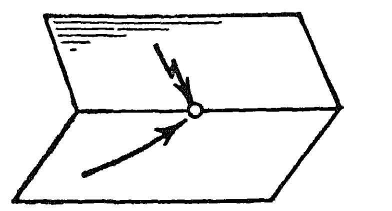
Koestler pronounces the crisis "profound" and asserts that it must remain so until at least two conditions are fulfilled: "The final integration of national states into a global whole, and the adaptation of social organization to changes in the natural environment, that is, to the level reached in the technique of the exploitation of natural resources." But just as the neurotic may not survive a succession of crises because he is too sick to begin with, is unable to adjust his already unbalanced nervous pattern to fresh circumstances, or because the demands upon him may be too numerous and vehement, so it is unlikely, Koestler thinks, that western European civilization "has a sufficient regenerative span to survive until it attains this aim." Exactly where this leaves us is not clear.

SO MUCH for what, despite its length, is an extremely sketchy recapitulation of Koestler's large work. It would have been a good deal easier, I am convinced, to summarize in the same space Kant's *Critique*, Lotze's *Microcosmos*, or the writings of Arnold Toynbee.

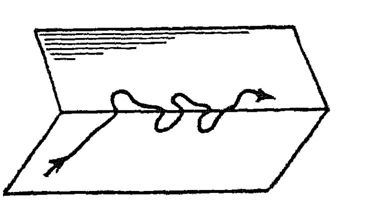
Apparently the seriousness of the subject and Koestler's conviction that this represents his *magnum opus* interfered with his well-known verbal dexterity. The result is something to behold. As he himself frankly admits, in trying to "strike a precarious balance between the claims of the general reader and of the specialist" he achieved a work in which "verbose passages boring to the scholar alternate with others over which the general reader may stumble." Not only is the writing afflicted with jargon and painful technical coagulations, but it is also evident that for fear of being thought an amateur in these many disciplines, Koestler wrote as only an amateur saddled with such a fear would write.

He is invariably long-winded and turgid, often unprecise and superficial. For example: "The manifold fields or schemata of mental operations are selective matrices of acquired habits. They are, needless to say, not linear chains of conditioned reflexes but integrated habit patterns of extreme plasticity and adaptability. . . The concomitant increase of imaginative inertia and 'clumsification' deprives the emotive of its lithe adaptability and supplies the sneer at unorthodox forms of art. . . Art is surprise in permanence . . . Benvenuto Cellini's golden saltcellar for Francis I is a source of aesthetic pleasure as well as a receptacle for salt. For—and this is the essential point—as it only functions as a receptacle of salt for a few seconds during a long meal, what is it doing the rest of the time?" This latter question has baffled me for some years, but I regret to report that Koestler, having posed it, fails to give an answer.

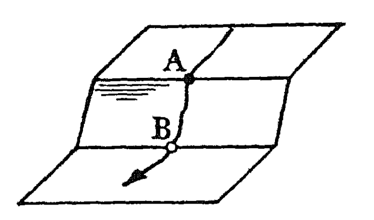
What is new and original in these many pages? Koestler's theory of the comic, to which half the book is devoted, is largely a contrivance of borrowed parts with a new panache. The concepts of operative fields, selective operators, junctions and so on, contain no real innovations. "Bisociation," for all of Koestler's exertions to pass it off as a profound and revolutionary concept, proposes nothing essentially new. Koestler's theories of biology, especially of brain function, are naive restatements of certain current views; as a psychologist he adopts the "holistic, or organismic or Gestalt approach," with a few home-made embroideries He strives to emphasize the difference between his theories



A JOKE is diagrammed by Koestler as intersection of fields. Listener laughs when narrative meets flash.



STREAM of consciousness wanders among fields. Reactions to stimuli depend on field tuned in at the time.



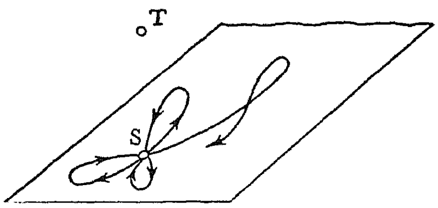
CHANGE in stream of consciousness requires a "junctional concept." In the diagram this is between A and B.

of frustration, neuroses and social ills and those of Freud. He avers that his own theories are sustained by "overwhelming" biological evidence; but what he adduces by way of proof is certainly less than overwhelming, though from my standpoint Freud's reductive simplifications are equally unsubstantiated. In short, Koestler advances old ideas, buttressed by current scientific hypotheses, many of the most speculative kind, the whole loosely bound together in a vague, grandiose, metaphor-ridden *Welt Philosophie* which smells a little of Hegel, Spengler and Freud.

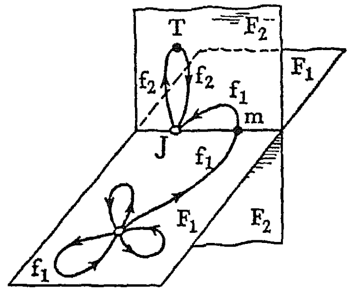
Where Koestler conveys a first impression of originality is in his exposition of scientific ideas by the use of beguiling metaphors and enticing analogies. He senses the dangers inherent in this method of proof and warns of them, but the ingenious teller of tales triumphs over the amateur philosopher and scientist. "Similitudes," said Thomas Fuller, "are the windows which give the best light," but the light of Koestler's similitudes is too often deceptive. The humor diagrams are inoffensive so long as it is clear that their purpose is only to show abstract relationships of abstract classes of ideas. Before long, however, one is led to believe that the separate planes of the diagrams have their physical counterparts in the brain, that each wiggling arrow is a wiggling motion in the brain cells. The very term "cognitive geometry" is ridiculously misleading if only in its implication that mental behavior is expressible in precise mathematical language. Koestler's description is complicated by the fact that at various times he likens the brain to a radio receiver, a tuning fork, a high-tension generator, a reservoir, a piano, a smooth pond, or a pond with ripples. It may be, I suppose, that the inside of the head corresponds to any or all of these objects, or it may, as in C. S. Sherrington's famous image, resemble a "great ravelled knot" twinkling with the tiny lights of thought and emotion. Yet until the matter has been settled I continue to feel uneasy, for it seems to me I have the right to know when deciding whether or not to subscribe to Koestler's theory how my head measures up to a Steinway, a Philco or a Westinghouse quarter-horsepower motor.

KOESTLER'S extension of the self-assertive and self-transcending tendencies to the "inorganic level" leads to other strange conclusions. Thus, "energy concentrations," as in elementary particles, and "the formation of molecules, crystals, and so on" are not merely examples of "structurally differentiated integrated (*sic*) patterns," but are "genetic precursors" of the two main behavior drives. And, "inertia, centrifugal momentum, free valences and so on" are in the same class as a malicious witticism in evincing "autonomous or self-assertive tendencies." It would be equally convincing and equally portentous—having first asserted that all things either gather or disperse, rise or fall, are positively or negatively charged, male or female, hot or cold—to deduce the nature of the world from any of these antitheses. In Koestler's dream all animals, vegetables, minerals and ideas are kin either to Francis of Assisi or to the practical joker. He says: "The first schoolboy to have the revolutionary idea of sawing through the legs of the teacher's chair was obviously a creative genius. His usual methods of satisfying aggressive impulses against other schoolboys . . being inapplicable in the teacher's case, the operative fields of habit are blocked, and a creative stress results."

It is in Koestler's analysis of "discovery," *i e*, the "Eureka process," that his theory attains full flowering and its ripest absurdity. "Eureka!" it will be recalled, was Archimedes' cry as he ran naked



THOUGHTS of Archimedes before his great discovery are schematized thus. S represents the starting point.



AFTER DISCOVERY Archimedes' mental processes followed this path. At point T he exclaimed, "Eureka!"

through the streets of Syracuse, having just discovered, while taking his bath, how to determine whether there was an admixture of silver in the allegedly pure gold crown given to Hiero, the Tyrant, by his jewelers. The discovery was that of the hydrostatic law which states that the amount of weight lost by a body when immersed in water is equal to the weight of the water displaced. Koestler's version of "Archimedes' reasoning," which makes the greatest scientist of antiquity appear to be something of a half-wit, includes a diagram to show the condition of Archimedes' mind *before* the famous bath. It is shown in the top diagram on this page.

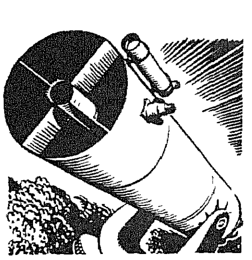
Koestler explains that Archimedes for some time failed to connect "the sensu-

ous and trivial associative contexts of taking a hot bath with the scholarly pursuit of the measurement of solids." But at last he managed, by self-transcendence, to rise above the sensations of "heat and cold, fatigue and relaxation, sex and beauty and so on," and by a supreme effort wrenched his mind into a cusplike condition, portrayed in the bottom diagram.

Koestler, apparently having been there while the thing was taking place, tells us finally that the exact moment of the great discovery was when "Archimedes saw his familiar hairy body as 'a solid which displaces a given amount of water.' "

THE MAIN flaw of the book, apart from its occasional sweeps of nonsense, its pretentiousness, pseudo profundity and non-stop quality, is its sterility. For all its bulk it says very little, because Koestler has very little to say. It lacks a real, driving principle or insight which could lead to fruitful conclusions. Despite Koestler's repeated denial that he advocates a simple dualism of nature, he seeks in fact to describe all events and substances, organic and inorganic, by a tautologous formula of "A or non-A." Nowhere is there a satisfactory explanation, in primitive terms, of the cause of either of his "tendencies" or of the mode of their evolution. His essay is studded with generalities about the nature of "cognition" but nothing concrete is said about how we come to know what we think we know. The attempts to formulate a serious, comprehensive theory of knowledge—essential to any such ambitious effort—are of the most jejune kind. Indeed, while Koestler pretends to a deep penetration of the classic problems of philosophy, he fails in fact to address himself to any of them. It never seems to occur to Koestler that a balanced, thorough examination of any mental state requires what one might call "algebraic" more than "geometric" reasoning. Such abstract factors as order, probability, inference, transformation, among others, are of course at the root of thought processes. Koestler mentions none of them. And as for social and political circumstances, it is amusing to note that by his own standards Koestler, the reformed Communist, has elevated the Soviet Union—insofar as it practices Marxism and pursues a rigidly planned economy—to a position at the apex of the hierarchy of "social wholes." For in Russia, where the rights of the individual are subsumed to the needs of all the toilers, "self-transcendence," in theory at least, would seem to have attained its apotheosis. I should not have thought it was the author's intention to prove this.

You may find a variety of attractive wares in Koestler's literary, philosophic, scientific and artistic delicatessen, but if you are shopping for insight and outlook, I suggest you go elsewhere.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

NO well-advised amateur starts by making so elaborate a telescope as the 10-inch reflector shown in the illustration on page 61. This is a second telescope, designed by an amateur who had been satisfied to start more humbly with the beginner's six-inch. After using it long enough to acquire ideas based on actual experience, he applied that experience to the design of his advanced instrument

Edwin F. Bailey, assistant at the Fels Planetarium in Philadelphia, made the 10-inch mirror, and the late John ("Everybody's Friend") Schaad, foreman of the optical shop at the Frankford Arsenal, made the diagonal. The mounting was designed and made by the owner, D. Robert Yarnall, of the Yarnall-Waring Company, Chestnut Hill, Pa., manufacturers of power-plant specialties. "There is nothing unusual about the design," Yarnall writes in reply to an inquiry, "except perhaps the axes, which I made especially heavy because the amateur telescopes that I have seen and used were inadequate in this respect. The hollow shafts are made of seamless tubing. A smaller tube was slipped into and pinned to a larger tube, then the assembly was turned to two-inch outside diameter for the smaller size, three-inch for the larger.

"The two yokes in which these shafts revolve are fabricated of 1/4- and 3/8-inch steel plate. The tube is held in a yoke of 1/4-inch steel plate, and may be rotated to turn the eyepiece to the most comfortable position for observation "

This use of steel plate for the parts of a telescope mounting is so direct a method for obtaining a neat and rugged mechanism that it perhaps merits the special appellation "fabricated steel plate construction."

The Yarnall telescope is semiportable. When not in use it is trundled on heavy casters into a closet near the top of Yarnall's house. When it is used it is moved out of doors to a deck covered with 3/16-inch steel plates. These distribute the load. Hand-operated screws on the four feet of the pedestal are run down to the steel plates after the polar axis is pointed to the North Star. Its orientation is conveniently checked by a north-south line painted on the steel plates.

Final adjustment of the polar axis to the altitude of the pole is made possible by a specially designed small-angle hinge between the sloping top plate of the pedestal and the bottom plate of the polar-axis yoke The crosswise hinge pin at the top, retained in its grooves by a small bolt and spring washer, is a rod of 1/4-inch brass. A hand screw near the bottom of the yoke member serves to adjust the vertical angle of the hinge, and an intermediate pair of screws holds the angle chosen. "This has worked out very satisfactorily," Yarnall states.

"The tube," he continues, "is designed so as to rotate easily in the supporting yoke, and this too has worked well " Two fixed lengths of Monel metal jack chain, attached permanently to the respective ends of the wyes of the tube yoke, pass around the tube in two deeply grooved brass stiffening rings. At their other ends these chains have eyebolts with wing nuts, and these tighten against slotted faces on the opposite wyes. To rotate the tube, the wing nuts are temporarily loosened. The tube is built up of six light-weight steel T-sections.

While the Yarnall telescope has a 10-inch mirror, the diameter of its tube is a full 12 inches The value of this feature has been recognized more frequently since it was embodied in Russell W Porter's revision of the Springfield type of mounting 12 years ago. It is believed by some that its advantage will be seen if the mirror is Foucault-tested in the tube. According to amateurs in Chicago, a small tube often produces on the mirror the appearance of having a turned-up edge. This is attributed to a layer of cool, dense air adjacent to the metal

An examination of the telescope and an analysis of its blueprint tend to lessen the initial impression that it may be hard to build. Many amateurs have access to the necessary machine tools. Yarnall, who could easily have turned the blueprint over to his plant for manufacturing, instead made nearly the whole telescope in his small shop at home. He did not, however, have adequate machinery for all the parts "I am much too fond of doing work with my own hands," he says, "to share all this pleasure with our shop.

"When the telescope was completed," he continues, "I soon found that my arms were not long enough to reach the valve handwheels on the worm drive for rotating the axes, so we attached a flexible shaft to each worm spindle and then added another handwheel on the upper end. This convenient extension makes it possible easily to operate both axes during observation.

"One capstan-operated locking screw is applied to each of the axis worm wheels for convenience in major movements of the telescope tube. To facilitate examination and dusting of the mirror a cover plate was added to the bottom of the tube Although seldom used, it has been found a convenience.

"The telescope has given a great deal of pleasure to our family and to many neighbors in the surrounding area who had never had a chance to look at the stars."

ELLISON'S condemnation of the dry-paper, dry-rouge polishing lap for telescope mirrors, contained in *Amateur Telescope Making*, page 368, three years ago led Father M. Daisomont of Ostend, Belgium, to send this department a printed polemic on the virtues of that ill-reputed method. From his communication the two following paragraphs are abstracted.

"Reverend Ellison argues that paper laps cannot be deformed and that they cause scratches My mirrors show no scratches, and the claim that the paper, because of its thickness, renders the coincident curves of mirror and tool no longer the same radius by a gross amount is erroneous. Calculation shows that the difference thereby introduced is only 1/250,000-inch. The paper, pasted on the glass tool, is brushed shaggy with bristles and fits after a few strokes.

"Polishing on pitch gives good results. Polishing on paper is at least as good, but far simpler, cleaner, more manageable. Foucault made wonderful mirrors with this, his method. It can produce real gems. As for pitch, send it to the devil It will then be in its element "

In January, 1947, this department, seeking only the facts, published a theoretical refutation of Ellison's claim that a sheet of paper throws mirror and lap out of coincidence by the amounts he indicated. The amount proved to be about the same as Father Daisomont had stated This department then invited him to furnish instructions for the paper lap, together with a small sample of the paper he used. These were received two years ago. He wrote, "I send the exact description of how we prepare and use paper laps.

"It is essential to use paper of excellent quality, pure, without defects, unsized We think well of duplicating paper 1/10-millimeter thick Make flour paste of soft consistency and strain it through fine linen to avoid lumps. Clean the tool, rub on a light, uniform layer of paste Rinse paper in water, remove excess water between blotters, lay it at once on the tool, and roll out excess liquid with hand or roller. With a knife tip remove any hard grains in the paper.

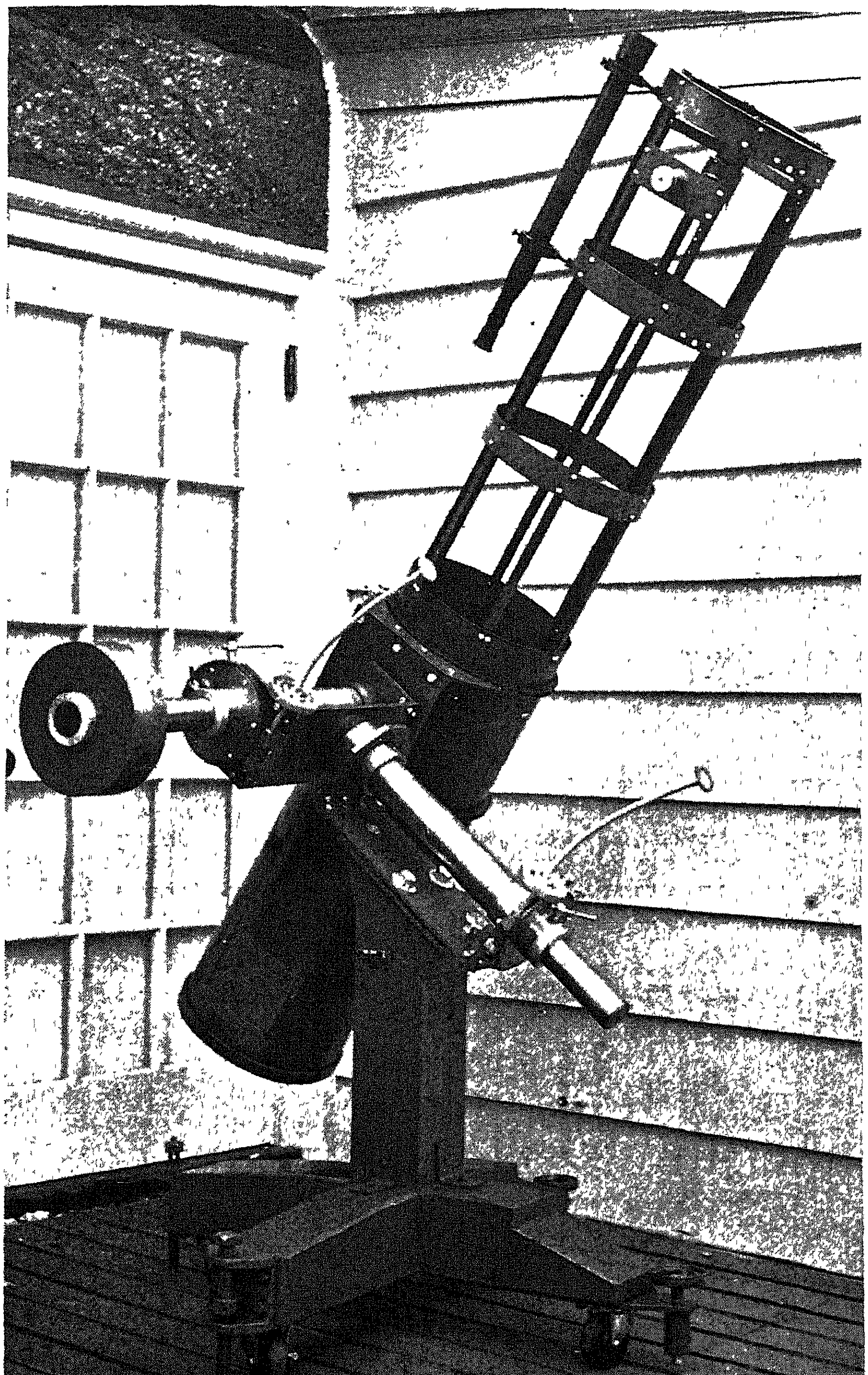
"When it is dry, cut around it with a razor blade, leaving a millimeter to fold

down. With an old toothbrush rub the paper to raise a light down. With the hand put on a very little dry rouge, uniformly. Remove surplus rouge with a toothbrush. The rouge layer should be so light that the paper may easily be seen. If too thin during work, add a little rouge."

Copies of these instructions, with little samples of the Belgian paper, which a New York paper manufacturer has called ordinary mimeograph paper, have been sent from time to time in the past two years to approximately 25 individuals and groups in the U. S. Most of these declined to make the test Some of them pointed out that in *Amateur Telescope Making* Ellison had already settled the matter. However, several did try the paper lap.

In July, 1947, John M. Holeman, of Richland, Wash., reported. "The paper lap is fast but gave a 'lemon-peel' finish, though not so bad a one as a felt lap. Under test my mirror, polished four different times, looked like blistered paint or ripple glass. The figure is easily controlled with paper. Turned-down edge is not so bad as with the soft pitch many use The drag is great and a 10-minute spell of polishing takes a lot out of one. After fine emery I polished in half an hour. The lap is so fast that it is hard to figure with it.

"Making the lap conform is the chief difficulty Despite theory, the paper's



Yarnall's fabricated steel plate telescope mounting

thickness of something does distort the curve and the edge polished first. This can be handled by watching for it and buffing down the lap with a suède leather wire brush—at the cost of as much work as channeling a pitch lap."

In March, 1948, J. J. Peabody and Dale Bufkin, of Elgin, Ill., reported: "We strongly suspect that 'Daisomont' is Albert Ingalls in disguise! We battled as follows With a six-inch f8 mirror we tried eight grades of paper from .002- to .008-inch thick. We polished 180 hours on our machine at various speeds and under pressures 0 to 25 pounds, the lap eight inches in diameter. Also tried it three hours by hand. Extreme caution is needed to avoid scratches We tried rouge, cerium, Barnesite. In every case, gross lemon peel showed under test. On a pitch lap this vanished at once. Back on the paper lap it reappeared. From theory, you admitted Ellison's error about the fit of curves, but in practice he is right, they just don't fit. Radius of outside zone came out 12 inches longer than central zone"

W. A. Calder, professor at Agnes Scott College, Decatur, Ga., reported: "Tried three times to polish, using mimeograph paper, Scott tissue, rouge, Barnesite, dry, then with kerosene, again with turpentine. Results inconclusive. I finally broke down and put the mirror on a pitch lap, which did wonders in a few minutes."

Rudolph Moulik, of Cicero, Ill., reported that the paper lap seemed to be good when tested on two four-inch convex surfaces. However, since convex shapes cannot be tested by the Foucault method, the state of the surfaces could not have been studied He attached the paper with thin varnish and found that it was difficult to keep good contact. He polished with Barnesite.

Shown some of these reports, Father Daisomont replied in December, 1947: "There is certainly something wrong with the work of your American friends." His claims, many of them so emphatic and extensive that there is not space to repeat them here (our Daisomont file is now an inch thick), do indeed point toward the conclusion that somewhere there is a large discrepancy, especially in view of the fact that in one of his 11 letters he mentioned that he had just polished and figured a six-inch f8.5 mirror in 10 hours on a dry paper lap and that *it showed the image of Saturn very well at 350 diameters.*

Therefore this department will pursue the discrepancy further. To that end it has asked Father Daisomont for a little of his rouge and enough paper for a lap, and will try to follow his instructions without the slightest deviation. (It has also sent him Garnet Fines and told him that after their use, glass on glass, not only the large type named by Ellison in *ATM*, page 79, but the text type of *ATM* could be read through the mirror, dry, held seven inches below the eyes and seven inches above the page, also that Barnesite, likewise sent, would then polish the mirror on pitch, its sinful disposition atoned for by speed and its fragrant aroma, in two hours)

SUDDENLY the images of the stars in a telescope on a rooftop in Washington, D. C., began to dance. They moved rhythmically for four minutes, then stopped. The puzzled telescope owner hurried downstairs. His wife had been beating eggs Only the blurred images of the stars revealed the resulting microseisms of the house, but the telescope magnified them exactly as many times as it magnified

Ideally a telescope at the top of a building should rest on a solid masonry pier descending well into the earth and slightly separated from contact with any other part of the structure. For most telescope owners this stiff requirement is unrealizable. In defiance of it they erect telescopes on rooftops. Often the results are satisfactory (Ideally telescope mirrors should be made in cellar shops with uniform temperatures; but many made in evil temperature conditions prove good.)

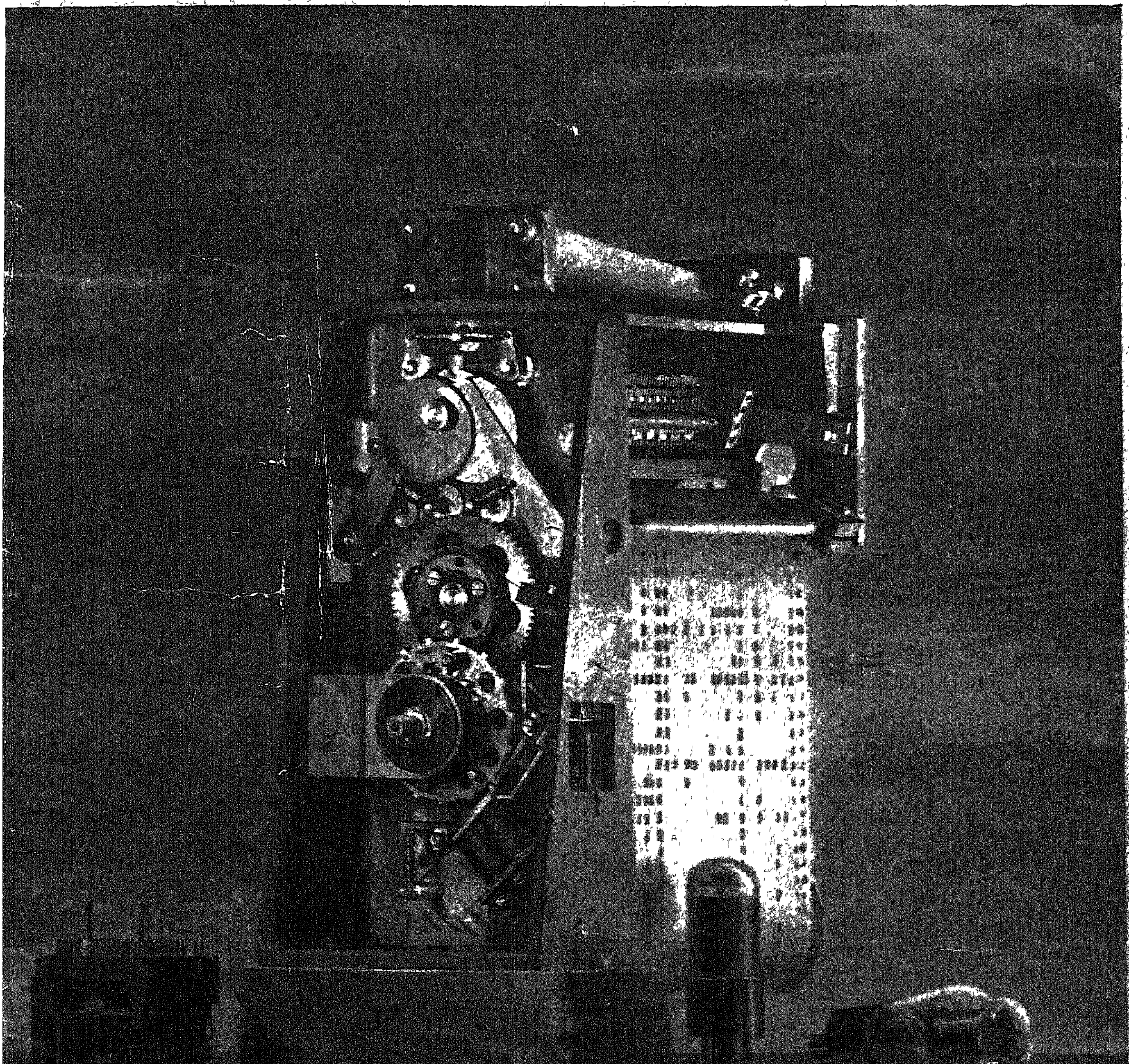
Stress analysis of a building should reveal how much a telescope will vibrate on top of it. A far less complex approach is to lug the telescope to the roof and try it there A collection of actual experiences with rooftop observatories may also throw valuable light on this question of telescope stability.

The following are two extremes. In the first an observatory dome was erected on top of a tall four-legged structure of heavy timbers, diagonally braced. Even then the star images danced whenever the observer batted an eye. Another person, if present, was forced almost to hold his breath. The bracing simply did not work as expected. In the second Russell Porter was asked whether a dog rapidly scratching its ear would agitate the 200-inch telescope His reply. "Bring on your dog."

In 1932 this department published a description of a dome on top of a large, two-story-and-attic frame house, with the telescope mounted directly on the attic floor. Recently the owners, George E and John R. Pelham, of Newark, N. Y., were queried about the kind of performance it gave The reply was, "We never had difficulty with vibration."

(A digression to describe the ingenious method of erecting this dome: First a hemispheric dome was built inside the attic, complete, unattached. Next a cylindrical dome ring, the vertical sidewall of the dome-to-be, was built beside it. Finally a hole was sawed through the sloping roof, the sawed-out portion was removed, the loose dome was pushed through this hole and shored, the prepared dome ring was lifted beneath it and the gap between it and the roof was

SCIENTIFIC AMERICAN

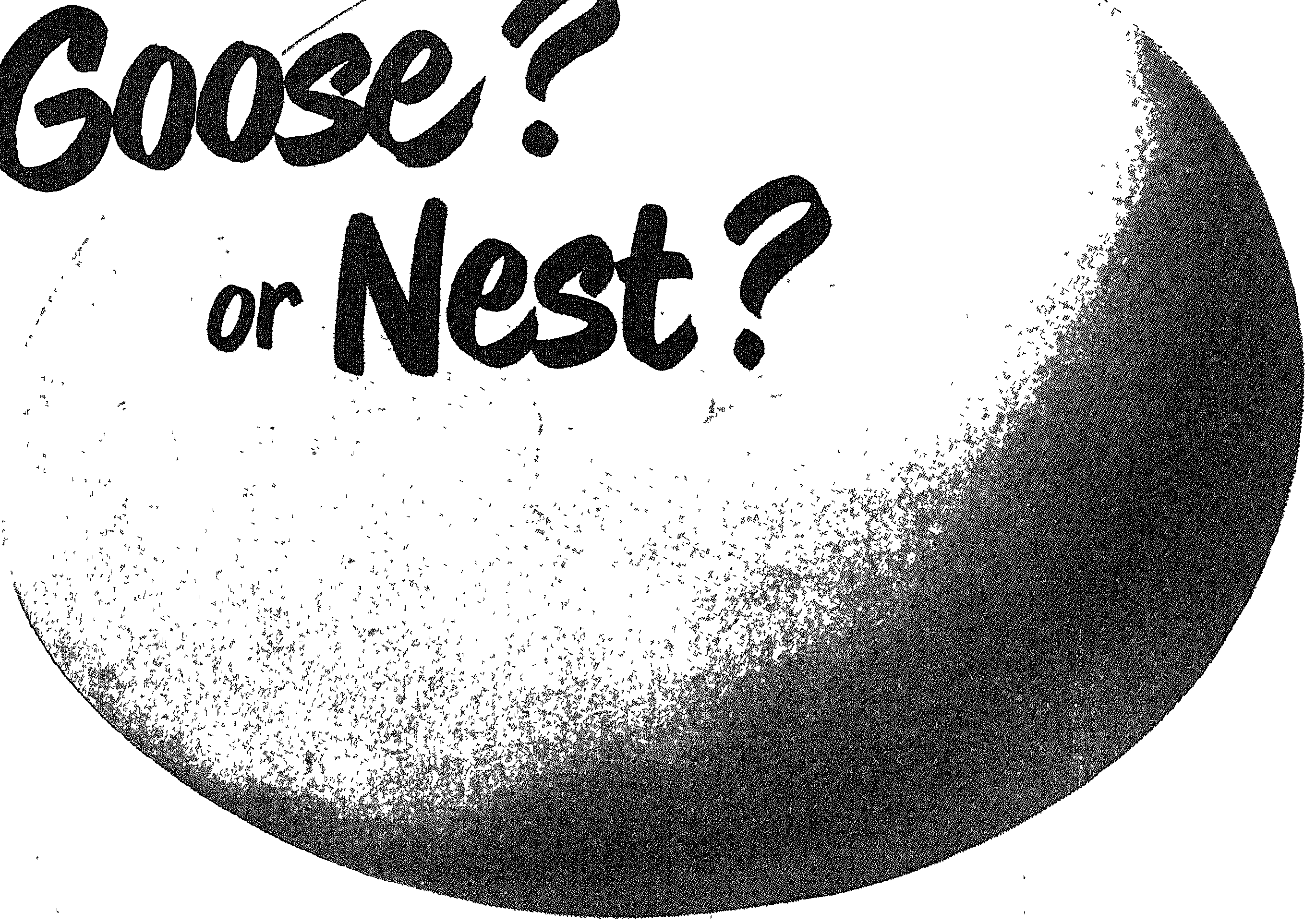


MATHEMATICAL MACHINES

FIFTY CENTS

April 1949

Goose? or Nest?



WHICH WILL YOU HAVE ?

For some reason, the goose egg stands for zero . . . nothing.

The nest egg, however, stands for a tidy sum of money, set aside for your own or your children's future.

It's hardly necessary to ask you which you'd prefer.

But it *is* necessary to ask *yourself* what you are doing to make sure you *don't* end up with a goose egg instead of a nest egg ten years from now.

The simple, easy, and obvious thing to do is to buy U. S. Savings Bonds.

Buy them regularly, automatically, on a plan that pays for them out of the month-to-month income you make today.

Millions of Americans have adopted this practically painless way to save up a nice nest egg for the needs and wants of the future.

In 10 years they get back $40 for every $30 invested in U. S. Savings Bonds—bonds as safe and solid as the Statue of Liberty.

There's a special Savings Bond Plan for *you*. Ask your employer or banker about it today . . . *and get started now*.

You'll soon realize that buying U. S. Savings Bonds *regularly* is one of the most important and comforting things you ever did!

Automatic saving is sure saving — U.S. Savings Bonds

Contributed by this magazine in co-operation with the Magazine Publishers of America as a public service.

"Madame X" was the code name, during research and development, for an entirely new system of recorded music . . perfected by RCA.

The remarkable background of **"Madame X"**

Now the identity of "Madame X," the *unknown* in a long search for tone perfection, has been revealed. From this quest emerges a completely integrated record-playing *system* — records and automatic player — the first to be entirely free of distortion to the trained musical ear . . .

The research began 11 years ago at RCA Laboratories. First, basic factors were determined—minimum diameters, at different speeds, of the groove spiral in the record—beyond which distortion would occur; size of stylus to be used; desired length of playing time. From these came the mathematical answer to the record's *speed*—45 turns a minute—and to the record's size, only 6⅞ inches in diameter.

With this speed and size, engineers could guarantee 5⅓ minutes of distortion-free performance, and the finest quality record in RCA Victor history!

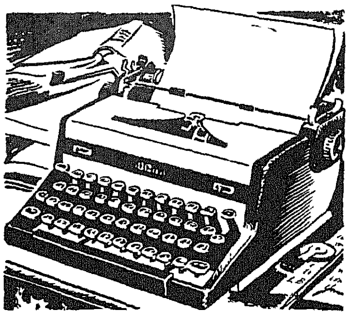
The record itself is non-breakable vinyl plastic, wafer-thin. *Yet it plays as long as a conventional 12-inch record.* The new RCA Victor automatic record changer accommodates up to 10 of the new records—1 hour and 40 minutes of playing time—and can be attached to almost any radio, phonograph, or television combination.

Not only records are free of surface noise and distortion—the record player eliminates faulty operation, noise, and cumbersome size. Records are changed quickly, quietly . . . RCA Victor will continue to supply 78 rpm instruments and records.

This far-reaching advance is one of hundreds which have grown from RCA research. Such leadership adds *value beyond price* to any product or service of RCA and RCA Victor.

RADIO CORPORATION of AMERICA

World Leader in Radio — First in Television



Sirs

"Trial by Newspaper" is an outstanding job and you are to be congratulated. It points the way to more analyses of the same kind on subjects that are perhaps even more crucial to the world, although civil rights certainly is a most important one.

I have a question I would like to ask. First, wouldn't it be highly important in measuring the effect of the pro and con statements as you determined them to show also the circulation of the newspapers? I am convinced that the effect on Dr. Condon of the unfavorable handling generally was multiplied many times over by the far larger circulation of those papers that can be considered hostile to him compared with the circulation of those that might be considered sympathetic, and that the survey was misleading to that extent. Perhaps the total number of statements you worked with should have been multiplied before you started your percentage calculation by the number of times each statement actually appeared in print.

GEORGE PAMPEL

New York, N. Y.

● **The circulations of the two groups of newspapers involved in the Condon study were compared in the report of the Columbia University Bureau of Applied Social Research.**

Scientific American, April, 1949; Vol. 180, No 4. Published monthly by Scientific American, Inc., Scientific American Building, 24 West 40th Street, New York 18, N. Y., Gerard Piel, president, Dennis Flanagan, vice president, Donald H Miller, Jr, vice president and treasurer. Entered at the New York, N Y Post Office as second-class matter June 28, 1879, under act of March 3, 1879 Additional entry at Greenwich, Conn

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LETTERS

Circulation, however, was not factored into the Bureau's content analysis, because of the difficulty of estimating the relative readership of news stories in the various newspapers. "Reader traffic" studies have indicated, for example, that the readers of the *Times* and *Herald Tribune* devote more attention to the news columns, as distinguished from other features in the papers, than do the readers of the *Daily News* and the *Journal-American*. There are also differences in the readership of various types of news in various newspapers. The size of circulation is a significant factor in studies of the effects of newspaper treatment of news stories, but it is not at present susceptible of precise evaluation.

Sirs.

I have just received your February issue regarding the investigation into newspaper reporting of the case of Dr. Condon. I have also read elsewhere about the recommendations of the committee of scientists which sponsored the study. The study is praiseworthy, and it seems to me inevitable that newspapers must give way before the cumulative pressure of this kind of evidence.

I am disturbed, however, to note the committee's recommendation that radio, television, still and motion picture photographers be barred from Congressional investigations. These are termed the "sensational media of mass communication." No medium of mass communication is sensational *per se*. I am very dubious about any effort to distinguish between those types of communications media which convey legitimate and necessary information to the public in a democracy and those which are "sensational" and therefore undesirable. Actually a distinction between camera reporting and verbal reporting is most artificial. If the American public has a stake in Congressional investigations and therefore has a right to information about the conduct and outcome of those investigations, then it has as much right to information presented pictorially as it has to printed information.

The business of creating legal restraints on the coverage of matters of legitimate public interest by whatever medium is something that all publishers, including yourselves, should be quick to oppose. These restrictive measures, called up out of an emotional reaction over a particular incident, often have consequences so far-reaching and so evil as to make the initial consideration unimportant by comparison. I sincerely hope that the legislation proposed by the

committee of scientists is defeated, not because I am not in sympathy with any effort to improve the quality of newspaper coverage, but because I feel you have overlooked something of very grave danger in your manner of handling it.

DWIGHT BENTEL

Head, Department of Journalism
San Jose State College
San Jose, Calif.

Sirs

. . . "Trials by newspaper" are nothing new, but the writers of the article in question approach the case of Dr. Condon from a new point of view with results that I hope that the newspapers themselves will study carefully I have long felt that the coloration and weighting of the news is a matter of great concern to the general public.

HAROLD L ICKES

Washington, D. C.

Sirs:

"Trial by Newspaper" is indeed an important contribution to our understanding of how the House Committee on Un-American Activities achieves its effectiveness as a colorer of public opinion. I am sure that the article will stimulate understanding and; I hope, action to restrict the power of evil which is now lodged in that Committee.

WALTER GELLHORN

School of Law
Columbia University
New York, N. Y.

Sirs.

It is seldom that a brief book review warrants a rebuttal. The review in your February issue of *The Universe and Dr Einstein* seems unfair to the author, reader and yourselves

Lincoln Barnett, the author, shows promise of becoming an increasingly important bridge between the scientist and the intelligent public. His superb reportorial ability was recognized by Dr. Einstein, who asked for permission to write a foreword to the book.

As your readers are scattered geographically so are their mental attainments. How few in this decade can have the embracing wide-field knowledge of current development that was possible in the years of Wollaston, Henry or Franklin. Don't you honestly think you have done a disservice to a very considerable portion of your readers by steering them away from the book?

KOERT D. BURNHAM

Essex, N. Y.

50 AND 100 YEARS AGO

APRIL 1899. "From the air employed in a liquid state for the purpose of liquefying and fractionally distilling argon, two other elementary gases have been obtained. A preliminary account of all these gases has already been given in the Proceedings of the Royal Society under the names of 'Neon,' or 'new,' 'Krypton,' or 'hidden' and 'Metargon,' and at the meeting of the British Association at Bristol, the discovery of 'Xenon,' or 'the stranger,' was announced. The removal of these gases from argon has put us in possession of pure argon."

"Prof. Robert Koch, the celebrated bacteriologist, will start some time in April for the tropics, at the head of an expedition to continue his investigations as to the nature and origin of malaria. It is hoped that his work will tend to mitigate tropical fevers. When he returned last year from the East African coast he advanced a theory that, in the case of human beings, mosquitoes played the part in communicating malaria which ticks played in the cattle disease known as Texas fever. He had reached the conclusion that where there are mosquitoes there is always malaria, and where there are no mosquitoes there is no malaria. His theory is that quinine taken at the right moment stops malarial fever, not by killing the germs, but by arresting their growth, and that a proper employment of quinine, with the establishment of mountain health resorts, would rid tropical fever of many of its terrors."

"At the last meeting of the anthropological division of the British Society of Natural Philosophy, Prof. Flinders Petrie gave a very interesting review of his investigations during the last five years. At different excavations in Koptos, Naquedeh, Abydos, and Hieraconpolis, relics were found dating back beyond the year 4,000 B.C., usually taken as the beginning of known history."

"The Paris Figaro has announced that Dr. Bra has found the microbe of cancer, and that there is reason to hope that the discovery may soon lead to a certain cure of that dread disease. Dr. Bra is modest and cautious in his statements, saying that it must be months before a definite announcement would be possible. What he has succeeded in doing, however, is to isolate and cultivate a parasite from cancerous tumors and to produce therefrom cancer in animals. The parasite is fungus-like and is certainly the specific agent of cancer. Dr. Bra has spent some four years in his researches on the origin of cancer."

"The recent experiments of Marconi in telegraphing without wires across the English Channel have entirely removed his work from the region of mere experiment and established it among the practical and extremely useful inventions. The main facts of the recent test are already familiar to our readers and require no reiteration here. In view of the large amount of visionary speculation that has been indulged in by some of the investigators of wireless telegraphy, there is something decidedly refreshing in the businesslike methods and practical results which have characterized the work of this brilliant young Italian."

APRIL 1849. "The ship Sea Witch, Captain Waterman, which arrived at this port last week from Canton, in the unusually short space of 74 days and 14 hours, has, it appears, made a series of passages on her course out and home again, surpassing in quickness any previously made by a sailing vessel. These passages make a voyage round the world, which he has effected in 194 sailing days. Her runs are as follows: 69 days from New York to Valparaiso, 50 days from Callao to China, 75 days from China to New York."

"We had recently the pleasure of examining a small but very ingenious machine, recently invented by Mr. Oliver T. Eddy, which promises, when perfected, to be of very great utility. It is an instrument which will print, with almost the perfection of an ordinary printing press, a single copy of any document, and with about the same rapidity as the document can be transcribed by a good penman. They are played on, as it were, striking keys answering to the letters of the alphabet, and the response is the instantaneous impression on the sheet."

"Mr. Alfred Smee, of England, has announced important discoveries in animal electricity. By a test which he terms electro voltaic, he has discovered that the termination of the sensor nerves are positive poles of a voltaic circuit, whilst the muscular substance is the negative pole. The sensor nerves are the telegraphs which carry the sensation to the brain and the motor nerves carry back the volition to the muscles. Should these researches be fully confirmed by other investigators, they must be regarded as the most important physiological discovery of modern times."

"Plausible fallacies are being brought constantly before the public as things wonderful, important and new. Exploded theories are continually re-resolving into fanciful or promising speculations. At the present moment at no great distance from this city, a perpetual motion has has been discovered—a self moving machine that is to astonish this before-bedarkened planet. The castings are now in the machine shop finishing up for the final triumph of man's genius, over the sneers and doubts and fears of all unbelievers. If people would just bear in mind that 'action must be equal and contrary to re-action, that every body must persevere in a state of rest or of uniform motion in *a straight line*, unless compelled to change that state by forces impressed upon it, and that every change of motion must be proportioned to the impressed force,' we would not hear of so many ingenious mistakes committed by many men who otherwise possess mechanical genius and skill."

"The Paris papers announce the decease of Mr. Moreton, an American, and it is stated that he has made a bequest, to the effect that two hundred thousand dollars shall be given to any person who shall succeed in constructing a machine capable of throwing off ten thousand copies of a newspaper in an hour!"

"The Area of the U. States is now nearly 4,000,000 square miles, equal to the support of 200,000,000 of population, leaving the country then less thickly settled than the State of Massachusetts. The Continent, when enclosed in the arms of the Union will be equal to the support of 500,000,000. The child may now be born who will see all this realized; we are on the eve of mighty events. This Continent will yet be under one government."

"In the year ending on the 1st of April 1849, there landed at this port, New York, two hundred and four thousand six hundred and thirty six immigrants."

Vibration Control

Columbian Humming Birds, one of the famous drawings from nature by John James Audubon.

Wing vibration, nimbly controlled, keeps the humming bird in flight, enables it to feed without alighting.

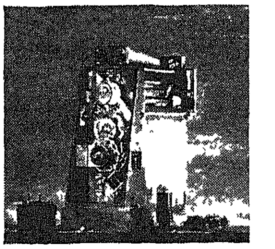
Electric vibration is the essence of telephone transmission. Voice, music, pictures, teletype—no matter what type of signal—the story is told by the frequency and strength of not one, but many vibrations.

Learning how to control electric vibrations to pin-point accuracy has been one of the basic jobs of Bell Laboratories scientists in their development of the "carrier" art which enables the sending of many more conversations over existing wires. Among their inventions have been oscillators, modulators, filters, coaxials, wave-guides, and radio lenses.

Constantly Bell Laboratories scientists discover new and better ways to control and adapt electric vibrations by wire or radio to the needs of the telephone user. Their pioneer work in this field is one important reason behind today's clear, dependable and economical telephone service.

BELL TELEPHONE LABORATORIES

Exploring and inventing, devising and perfecting, for continued improvements and economies in telephone service.



THE COVER

The painting on the cover shows some constituents of the International Business Machines Corporation's Selective Sequence Electronic Calculator (*page* 28). The twin triode vacuum tube at right center, one of 4,989 such in the calculator, is used in a counting circuit. Its ability to count 50,000 electric pulses per second is at the heart of the calculator's operation. To the right is another of the 12,500 tubes in the machine, a cold-cathode, gas-filled voltage regulator. At the left is one of the calculator's 23,000 electromagnetic relays. The type shown, approximately a two-inch cube in size, is capable of switching 12 independent circuits in five milliseconds and serves to stabilize control circuits At the center is one of the calculator's 66 individual tape-reading stations, with a continuous loop of tape mounted in reading position. It has been removed from the machine to expose the driving gears and electromagnetically controlled clutch. The unit can "read," or translate into electrical impulses, 55 rows of punched instructions or information per second. The bottom of the loop turns around a free-hanging cylinder. The latter is called by the IBM engineers a "yo-yo" because of its resemblance to the children's toy

THE ILLUSTRATIONS

Cover by Walter Murch

Page	Source
11	United Nations
12-15	Emil Lowenstein
16-17	Hal Fiedler
19	Jack Manning
20	Eric Mose
21-23	Jack Manning
28	Samuel W. Vandivert
31	Eric Mose
32-39	Samuel W. Vandivert
41	Matthew Greene
43	Francis P. Shepard
45	New York Public Library
46-47	James Lewicki
49	Christie McFall
50-51	National Lead Company
53-55	R. W. St. Clair
56	Esther C. Goddard
61	Philip F. Meyers

What GENERAL ELECTRIC People Are Saying

T. M. LINVILLE

Staff Assistant to Manager of Engineering, Apparatus Department

SOME NEEDS: A few technical things that industry expects young engineers to do are as follows. The things mentioned are just in the field of electrical apparatus; i.e., in only a small part of the whole industrial field.

¶Big steam turbines, so far, have a top efficiency of 34%. We are building one for 37%. In the future we must get maybe 45%.

¶Steam locomotives have a thermal efficiency of 5% to 10%. We want an electric locomotive with gas turbine, burning coal, with an efficiency of 18% or better.

¶We want stationary gas turbines burning oil or coal with efficiencies higher than 30% and bigger than the 5000-kw unit we are now building.

¶We want turbo-jet engines for air transportation to drive planes faster than the speed of time—to leave New York at 6 p.m. and arrive at San Francisco at 6 p.m., or even to reverse time and arrive earlier by the clock than we left New York, causing the sun to set in the east en route.

¶We need heat pumps with motors and control for heating commercial buildings and homes so that buildings will be totally electric.

¶We need atomic power to help supply increased electric energy from new resources. We need 345-kv transmission with stronger transformers and stronger circuit breakers to transport power from isolated hydroelectric and atomic power plants. We must have more output from turbine and water-driven generating units.

¶We must have new electric equipment for manufacturing processes to increase production per man-hour of labor. The motors we make must run faster, they must run more automatically, and we must produce them with less manpower.

¶We must have synthetic materials to make equipment less subject to damage by heat, oil or acid, or mechanical and electrical stress.

If you think men already have enough wealth, just look around and see how much we need better housing and more attractive environment, to name just two of many things. Then reflect that it is the men in industry, big and small, who are responsible for our increasingly higher standard of living.

Rensselaer Polytechnic Institute, Troy N. Y., November 18, 1948

★

H. L. ERLICHER

Vice President in charge of Purchasing and Traffic

CRITICAL MATERIALS: Many critical materials, which are in such worldwide demand today, should be—and I believe will be—selling at considerably lower prices than at present. High prices in a competitive economy have always provided incentives for increased production and for increased substitution, which in the long run have brought about a lowering of those prices. And we can expect those factors to operate today.

I believe that today's high prices for critical raw materials and finished products will be adjusted by one or both of two factors: buyer resistance and, most important, technological improvements and research, which increase output and reduce cost and thus reduce selling prices.

If we have in a certain sense taken the cream off the bottle of our natural resources, we have by the same token only skimmed the surface. There is a great deal of still unrevealed wealth beneath the surface that science and engineers are almost daily turning up for our use.

Toronto Electrical Club, Toronto, Canada, November 24, 1948

★

CHARLES E. WILSON

President, General Electric

ENGINEER AS CITIZEN: The issues confronting this country are plain, the stakes are high, and the degree of danger is apparent. The situation demands intelligent expression and action. It is unsafe for you to delegate the duties of citizenship to others because of your preoccupation with the slide rule. To withdraw into the protective and respectable cocoon of your immediate task is to assume the spurious mantle of a protected class.

AIEE, New York City, February 2, 1949

★

K. H. KINGDON

Assistant Director, Research Laboratory, In charge, Knolls Atomic Power Laboratory

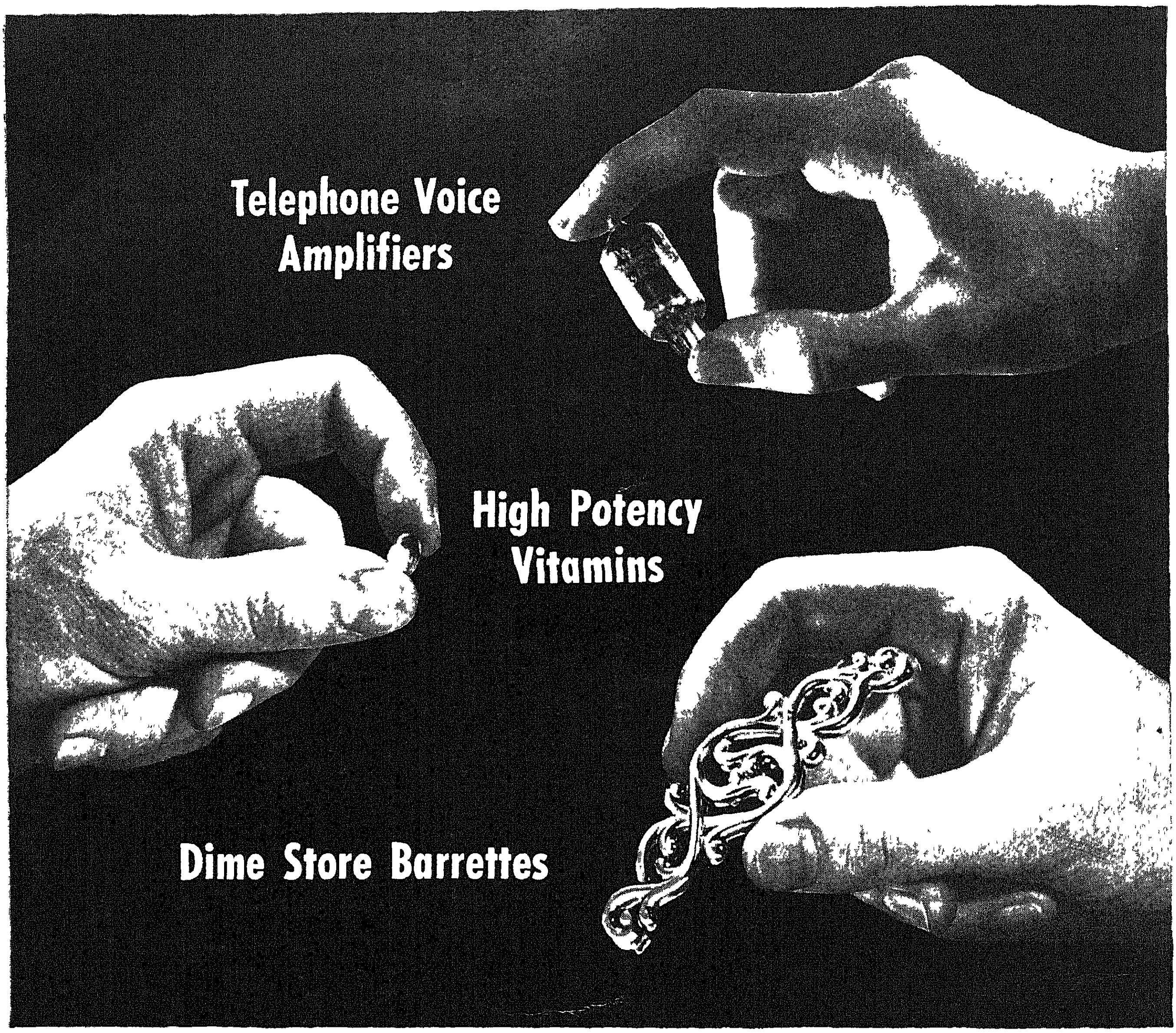
NEW ELEMENTS: A nuclear reactor may be used for irradiating materials so as to produce either new elements or materials with greatly changed physical properties. . . .

One might at first sight think, then, that here is a method for producing a great variety of substances having new properties. This is true, but we must keep very clearly in mind that these altered substances are going to be extremely expensive. For, if the production of these new altered substances involves the absorption of neutrons in the reactor, we have then lost the neutrons as far as the possibility of producing new fissionable material and power from these neutrons is concerned. If a new material of this sort is built up molecule by molecule by the absorption of neutrons, a simple calculation shows that the cost of this new material per pound is really tremendous in terms of the potential electric power which was sacrificed in using the neutrons to make this new material. Such use of the neutrons is obviously justifiable in the case of new fissionable materials like plutonium and uranium-233, but it seems likely at present that the industrial use of such artificially produced or modified substances will be limited sharply by their very high cost.

"General Electric Review" August, 1948

You can put your confidence in—

GENERAL ELECTRIC



. . . products of High Vacuum

YOU 'phone from coast to coast and converse as easily as though you were in the same room. The reason, a tiny electronic repeater tube that prevents voice fading. It works only because a high vacuum pump has exhausted air from the glass tube to a degree that closely approaches perfect vacuum.

Important vitamins for food fortification, pharmaceuticals and doctors' prescriptions are available *at moderate cost* because of high vacuum. Distilled under high vacuum the extract is purer—can be concentrated to high potencies.

Contrasting sharply to applications in the fields of electronics and bio-chemistry is the use of high vacuum in depositing metallic vapors on glass, wood, cloth, paper and plastics. Inexpensive but beautiful novelty jewelry, ornaments, barrettes, etc., are coated inside huge chambers from which air has been exhausted . . . a plating process that gives better results, cuts costs and permits bargain prices to a mass market.

These examples serve to emphasize the scores of different ways DPI high vacuum equipment is enabling new products and better products to be made at lower costs.

Perhaps high vacuum can work for you. DPI can aid in research, in setting up pilot operations, and can advise on engineering and building complete installations for profitable commercial applications of high vacuum. We invite inquiry.

DPi

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SCIENTIFIC AMERICAN

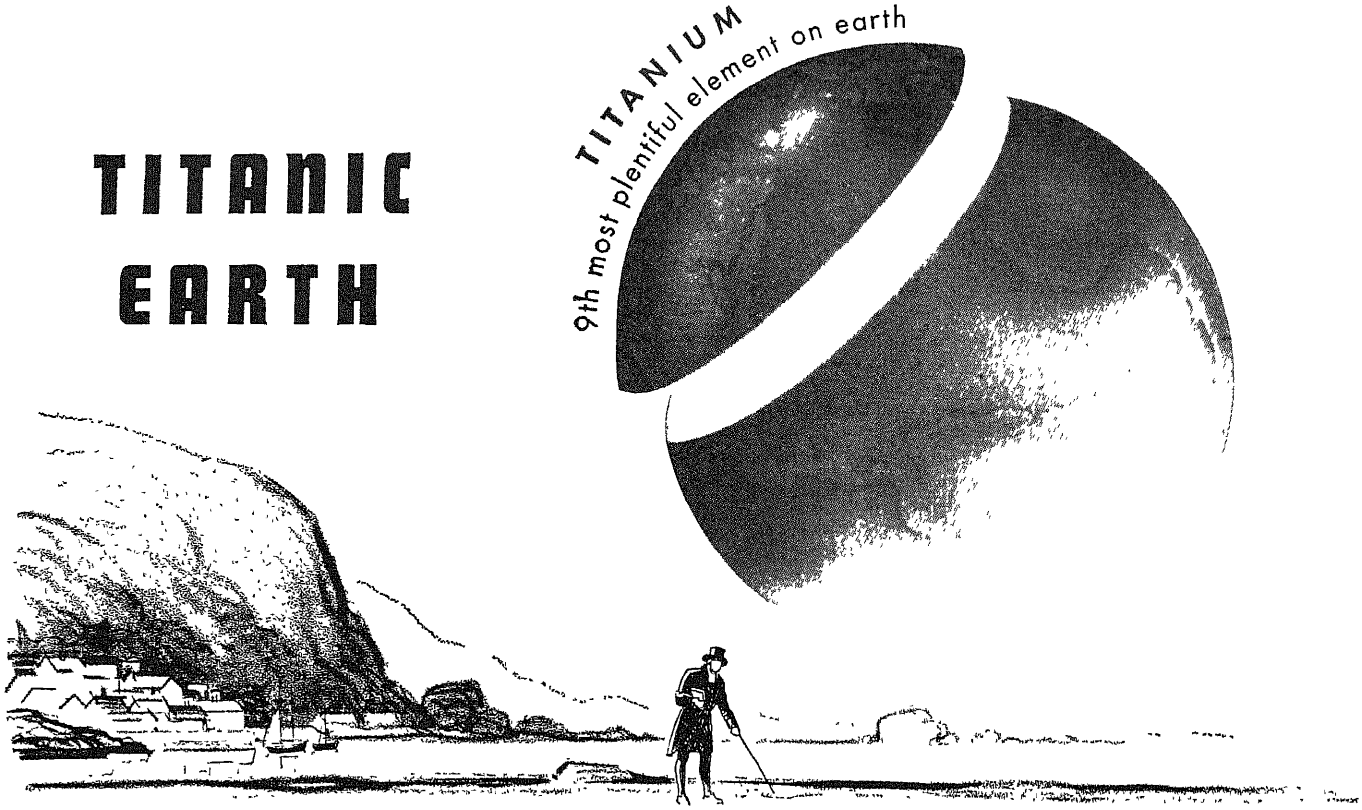
Established 1845

CONTENTS FOR APRIL 1949 VOLUME 180, NUMBER 4

ARTICLES

DEPARTMENTS

TITANIC EARTH



TITANIUM DISCOVERED

Back in 1791 an English clergyman, William Gregor, who liked to stroll and think on the beaches of Cornwall, became curious about the black sand he saw there. This gentleman of the cloth was also an amateur chemist and in this sand he discovered a new element Almost coincidentally an Austrian named Heinrich Klaproth (also discoverer of uranium and zirconium) extracted the same thing from rutile and named it "Titanic Earth" for the mythical Titans. Hence our name Titanium.

Thereafter titanium was found in various places including the Ilmen Mountains of Russia (ilmenite) but although it is the ninth element in order of earthly abundance, it remained a mere laboratory curiosity until 1908.

TITANIUM OXIDE

At that time Dr. A. J. Rossi, expert in the reduction of metals, mixed titanium oxide with salad oil to make a white paint. In another 10 years a pure oxide was being produced which quickly won success as a pigment. Paint, false teeth, face powder, tires, shoes, glassware, textiles, inks, plastics, paper consumed an increasing tonnage of titanium oxide but still the pure metal was beyond industry's reach.

TITANIUM METAL & NATIONAL RESEARCH

Titanium is an affectionate metal, over fond of oxygen and nitrogen when at high temperatures Even a fraction of a per cent of either makes titanium of little value as a structural material. Until recently there was no means of preparing titanium metal in a form sufficiently free of these elements to indicate any potential commercial value. Dr. W. J. Kroll of the Bureau of Mines has initiated many of the recent developments in titanium metallurgy by finding a means of preparing powdered titanium metal.

Only by exclusion of these gases can it be kept from embrittling combinations and when Remington Arms Company, a Du Pont subsidiary, laid its plans to produce metallic titanium in cast and rolled shapes, they knew that at National Research Corporation they could find the knowledge of vacuum technique that they needed.

The melting and casting of titanium was a natural for National Research We planned the process, designed the equipment and installed it. Today this National Research Corporation pilot equipment is handling the highest quality of commercial metal — not much compared with aluminum — nothing at all compared with steel — but so promising that millions will be spent by the industry within a few years to increase the quantity and lower the price.

USES OF TITANIUM METAL

Titanium stands fourth in abundance among the structural metals and there is plenty in the U S A. Tremendous strength, light weight, and remarkable corrosion resistance (comparable only to that of the noble metals) is a unique combination. Coming at a time when long-sighted people are viewing our metallic resources with alarm, it has an assured future With the price pulled down to a few dollars a pound or less, titanium will be of primary importance to manufacturers of aircraft, automobiles, electric devices, gas turbines, superchargers, marine hardware, rockets, optics, jewelry.

WHAT NEXT?

So, with the help of National Research's high vacuum know-how, another material has been taken from the test tube to the factory Where else can good men and ideas help — where can they help you? At National Research the best in brains, organization, equipment, and an unequalled accumulation of unique experience are available.

INDUSTRIAL RESEARCH PROCESS DEVELOPMENT
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SCIENTIFIC AMERICAN

APRIL 1949 VOL. 180, NO. 4

SOCIAL MEDICINE

The causes of disease are not entirely physical and biological. This relatively new discipline is presently exploring the sociological factors

by Brock Chisholm

IN OUR ever-changing social order medicine has assumed a new meaning and a new place during the eventful past few decades. New concepts and new tasks, emerging as the result of a 5,000-year evolution, have combined to create what is known today as social medicine.

Social medicine, which is not to be confused with the system called socialized medicine, is a philosophy and a science. With the greatly increased awareness of the relative importance of preventive as compared with curative medicine, it is now generally recognized that causes of disease are not to be found simply in physical and biological factors. Economic and social conditions increasingly are seen to play an important part in health problems. This being so, it would appear that the problem of health must be tackled not only from the strictly medical but also from the sociological point of view. Although medicine is more than 5,000 years old, and modern science about 150, it is only during the past 50 years that this idea has gained ground. Today there are few people who would deny that health is a fundamental human right for everyone. The community, therefore, should be obliged to afford to all its members health protection as complete as possible.

These facts have received formal recognition from no fewer than 64 nations. That is the number of countries which signed the constitution of the World Health Organization three years ago at New York, and in doing so promulgated the following principles:

"Health is a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity.

"The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition.

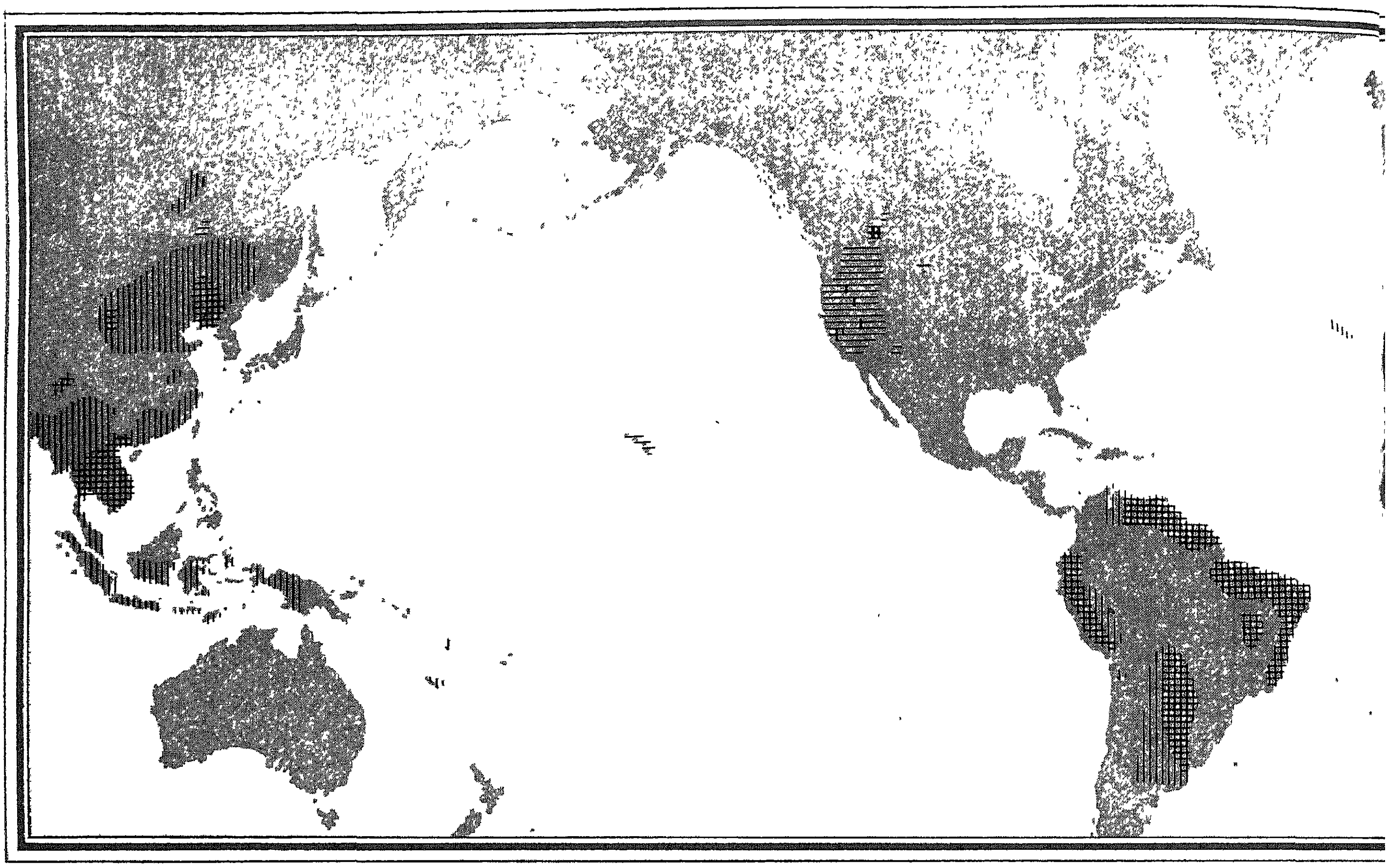
"The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest cooperation of individuals and States.

"Unequal development in different countries in the promotion of health and control of disease, especially communicable disease, is a common danger.

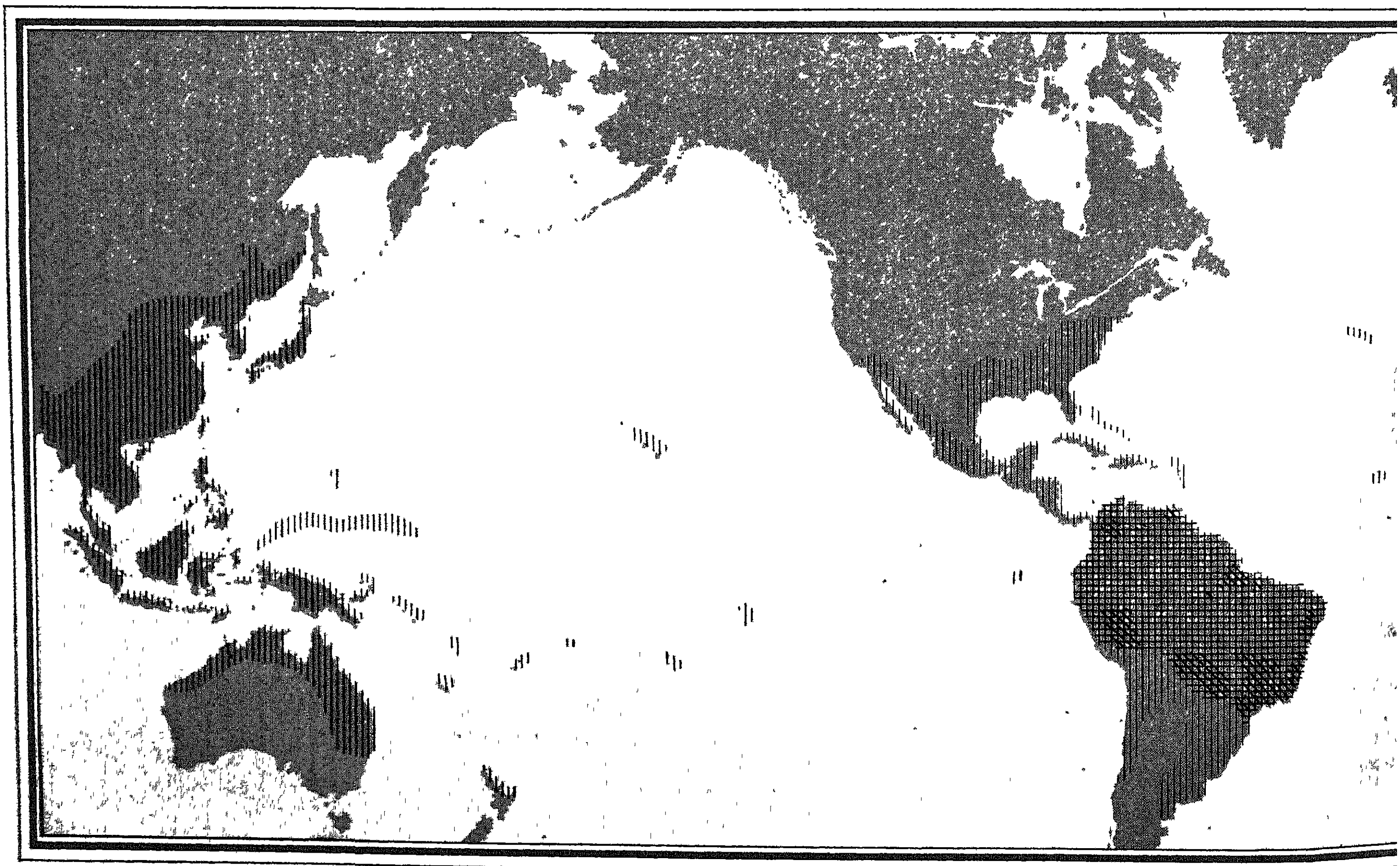
"Healthy development of the child is of basic importance; the ability to live harmoniously in a changing total environment is essential. . . .

"Governments have a responsibility

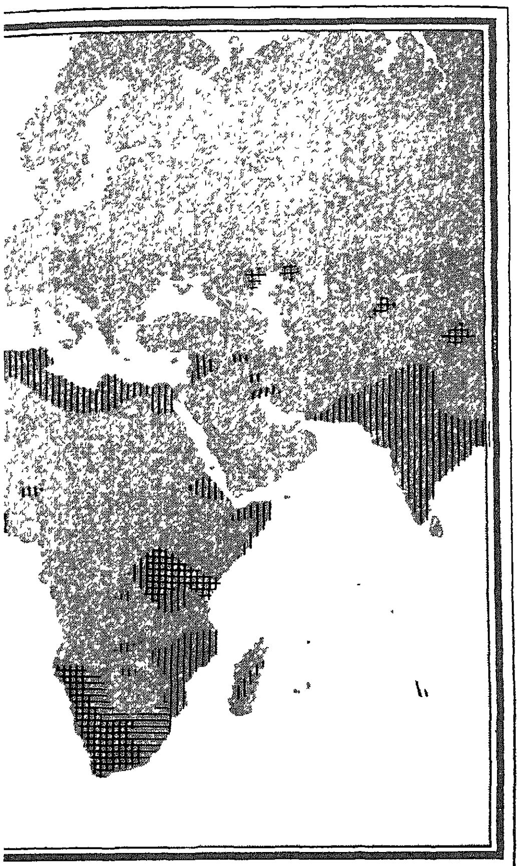
FIRST WORLD HEALTH ASSEMBLY met at Geneva in June of last year to constitute the World Health Organization as a permanent agency of the UN. WHO's charter enunciates the principles of social medicine.



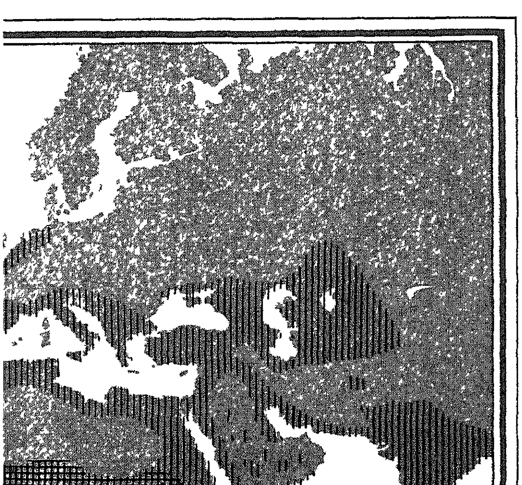
PLAGUE, which once ravaged Europe, has largely disappeared with Continent's rise in standard of living. It is still a problem, however, in all backward areas. Vertical lines represent human plague; horizontal lines, syl-



YELLOW FEVER, like plague, is most prevalent in areas that have a low standard of living. Darkest shading shows areas where yellow fever is a current problem. Lighter shading indicates endemic areas. Lightest shad-



vatic plague. The latter is borne by wild animals which infect humans.



ing shows areas where vectors of disease are common but disease is not.

for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures."

Medicine always has borrowed knowledge and methods from its sister sciences, first from physics, chemistry and mathematics; later from biology, parasitology, bacteriology. With the advent of psychology and the social sciences, a larger field of investigation and application came into being. Social medicine today has as its concern what we might call "total man" in relation to his environment. Thus social medicine includes not only clinical medicine and public health medicine but also social hygiene, industrial hygiene, mental health, medical rehabilitation, and so on. Furthermore its accent always is more on prevention than on cure. Every new development in the improvement of living conditions means an advance for social medicine. It embraces in its broad goals the improvement of hospitals and hospital services, the raising of standards of nursing and of nurses' working conditions, improvement of public health services, establishment of social security systems, promulgation of labor legislation, development of the social sciences, and the progress of economic organization in general.

Scientific progress brings new efficiency to medicine, and social progress demands that these benefits should be made available to the whole population. The World Health Organization has been created in order to help extend such progress to all mankind.

If WE look at today's world we find that technology has outrun social organization in every field of human endeavor. Science has developed more quickly than has society's adjustment to the new conditions that science has created. This phenomenon lies at the root of a great many of our present problems. Although humanity now has the technical "know-how" to produce all the food the people of the world could consume, more than half the population of the globe still suffers from malnutrition, if not outright starvation. We possess the technical means for making all the goods that the world's people need for decent living. Nevertheless, millions still exist on subminimum standards, and poverty remains the overwhelming curse of mankind. We have created astounding new transportation and communication facilities that have shrunk the globe to a small fraction of its former size. But we have still to develop enough mature people in enough places to be able to create a social organization that could permit the peoples of the world to live and work together effectively and peacefully.

What is true for the world at large is also true for medicine. Here, too, technology has outstripped social organization. Medicine has infinitely more to give to the people of the world than they actually get. We have the knowledge necessary to wipe out utterly a great variety of diseases, but these diseases are still among us on a very large scale. True, we have succeeded in overcoming certain diseases in the economically advanced countries, but we still have them and continue to breed them in economically backward regions where they remain a constant menace to all.

It has been shown that the advent of soap and its widespread use is very largely responsible for the fact that Europe has been rid of plague since the 17th century. Many other pestilences have disappeared from Western countries. The public and even doctors now consider plague, cholera, malaria, the various forms of dysentery, hookworm and leprosy largely as "tropical" or "subtropical" diseases. Yet many of these diseases occurred widely in Europe and in the U. S. when poverty, dirt, malnutrition, ignorance and neglect of sanitary needs were the common lot of most of the population.

To three quarters of the world these great scourges are still an ever-present threat. Nearly all of them are essentially "social" diseases. They are linked to alterable social factors rather than to climate, as the terms "tropical" or "subtropical" would imply. Because they still affect so many people in the world and because the means exist to combat many of them effectively, they are high on the list of diseases that WHO has chosen to combat first.

But what about our modern diseases—the disorders which today are endemic in the Western world? Europe and countries such as the U. S. now have new "social" diseases which, like the plagues of the Middle Ages, will be identified by future historians with our era. Among the chronic illnesses now widely prevalent in technically advanced countries are peptic ulcers, cardiovascular diseases, cancer, the chronic rheumatic diseases, neuroses, and diseases resulting from accidental injuries. Now, as in the past, diseases and death show a strong preference for the economically underprivileged, and health statistics prove the existence of a veritable *Almanach de Gotha* of diseases.

Morbidity and mortality rates all point to a progressive increase of acute and chronic diseases down the social and economic scale. In particular, the death rate from pulmonary tuberculosis, or the general infant mortality rate, is now everywhere accepted as a sensitive index to the social state of a community. In the United Kingdom, where analyses of occupational mortality are published at 10-year intervals by the Registrar-General's Office, some very revealing facts have come to light. In these surveys the population from 20 to 65 years of age is divided into five main social classes or groups. Group I includes the profes-

sional classes, Group III comprises skilled workers, Group V, unskilled workers. Groups II and IV cover intermediate types of employment Obviously a disease whose incidence increases progressively from Group I to Group V is social in character The diseases that show such a progression include tuberculosis; syphilis, cancer of the upper alimentary tract, of the larynx and of the skin, valvular heart disease (mainly due to rheumatic fever); myocarditis, arteriosclerosis, bronchitis, asthma, pneumonia, pleurisy, hernia, industrial diseases.

On the other hand, there is a group of diseases that shows progressively decreasing importance down the social ladder. Among these are angina pectoris, appendicitis, diabetes, cancer of the breast and ovary. It would thus be possible to classify the "well-to-do diseases," as opposed to the "poor man's diseases." The latter are generally far more deadly. Still a third group includes illnesses common to all social groups; they might be called "egalitarian."

THE INEQUALITY of the social strata in regard to disease and death is linked with factors which act either separately or together to produce the differences in vulnerability to disease. Among the so-called working classes the first of these factors is occupational exposure, which is reflected in the frequency of hernias and other diseases, due largely to accidental injury in heavy physical work, and in the incidence of skin cancer, which is favored by exposure to dusts, harmful liquids, filth, and so on. The second factor of importance has to do with the greater dangers that many common diseases bring to persons in the economically less fortunate groups. Whooping cough, for example, strikes as many children of well-to-do families as of poor ones. But the mortality from whooping cough is higher among the poor because of lower physical resistance, overcrowding, poor sanitary conditions, inadequate care and nursing, and infection at earlier ages.

Studies in social anthropometry have also demonstrated the influence of housing conditions, nutrition, economic resources and similar factors on such things as height, weight, growth and strength. In general there is no class inequality in size and strength among infants at birth, except in extreme cases. Within three months after a child is born, however, unfavorable social factors already have begun to show their effects in slowing up normal growth. In Norway, where children in private schools were compared with those in public schools, the group differences in height and weight averaged from six to 10 per cent.

Parallel to this physical inequality due to environmental factors psychologists have discovered intellectual differences that would appear to be due to similar causes The findings of social psychology—which concerns itself with such influences as religion, education, family, professional or social milieu, unemployment, poverty and illness—concur with those of social anthropometry. On an average, the further down the social and economic scale one goes, the lower the level of intellectual activity. While it must be recognized that part of this "effect" is undoubtedly cause, there is a great deal of evidence showing that lower intellectual activity can be and often is a direct result of milieu and living conditions. It would appear quite clear that mental growth, like physical growth, can be checked or stimulated by social conditions.

These and other related facts find daily confirmation in psychosomatic medicine, which in the treatment and prevention of disease concerns itself with both psychological and physiological factors and with functional as well as with organic symptoms

Surveys in various countries on the incidence of mental disorders show significant differences in the nature and importance of these illnesses according to social stratification. In Chicago, in Munich, in England, it has been demonstrated that the rate of manic-depressive illness is higher among the economically more successful groups of the community than among the less successful. Occupational surveys indicate a relatively high number of hysteria cases among business men, of psychopathic personality difficulties among student-artists, and of manic-depressives among the professional groups.

IT IS not yet possible to determine to what extent social and economic factors may be the cause of these particular differences. Here cause and effect cannot easily be untangled. It may very well be that these forms of mental aberration or tendencies toward them do not represent the effect of environment but are rather themselves a very important cause in determining what type of activity an individual engages in, how successful he is at this activity, and therefore what his economic status and over-all environment may become. For example, the manic-depressive in the earlier half of his life typically has enormous drive, energy and ambition, which very often lead to success in business. Or, to take another example, the person with psychopathic tendencies is far more likely to become a student-artist than to go into the more disciplined channels of endeavor. The professional classes tend to be composed of people who are driven by emotional imbalance, social conscience, ambition, highly active or even overactive intelligence. They may show later overt symptoms of imbalance, not as a result of their occupations but because these very tendencies determined the course of their lives in the first place.

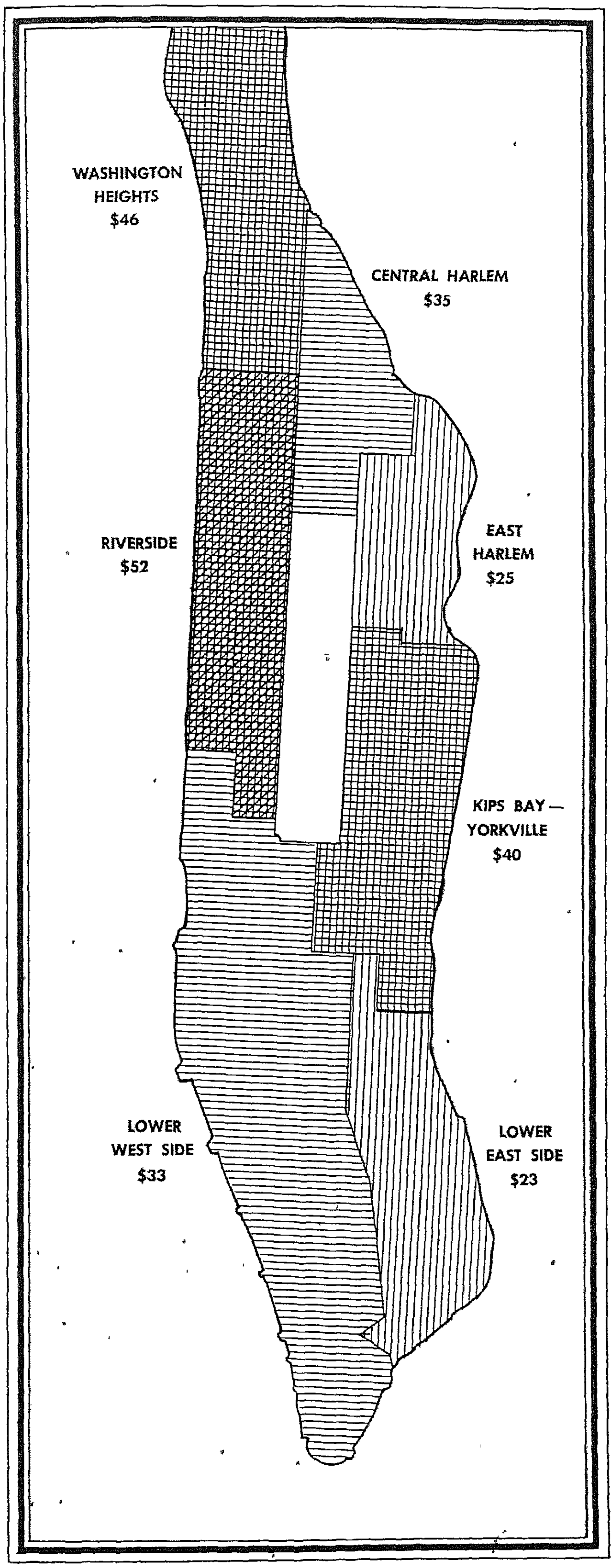
Thus undoubtedly there is a real correlation between economic status and mental health, or the lack of it. Further studies on a large scale will be necessary before anyone can identify clearly the cause-and-effect relationship. For the moment it is enough to know that such a relationship does exist.

In this situation, where social and economic factors are recognized as playing an extremely important role in the health of the peoples of the world, social medicine in the broadest sense must increasingly be applied. Many of the techniques of social medicine were employed for the first time on a large scale during the recent war Selective tests, for example, were used extensively in the recruitment of industrial manpower and armed forces personnel. Among other techniques applied were the rehabilitation of the wounded, the injured and the handicapped; the rational distribution of foodstuffs, the strengthening of health services with special emphasis on workers, expectant mothers and children; the extension of preventive and curative medical services, the development of social security systems. As a result, in the U. S. such significant indexes as infant mortality and tuberculosis mortality decreased notably, while at the same time the birth rate was increasing. In England, despite widespread destruction, restrictions, disruption of families, constant tension and near-total mobilization, the general death rate after an initial upward swing showed an early decrease. The same was true of infant mortality, which soon was lower than in peacetime.

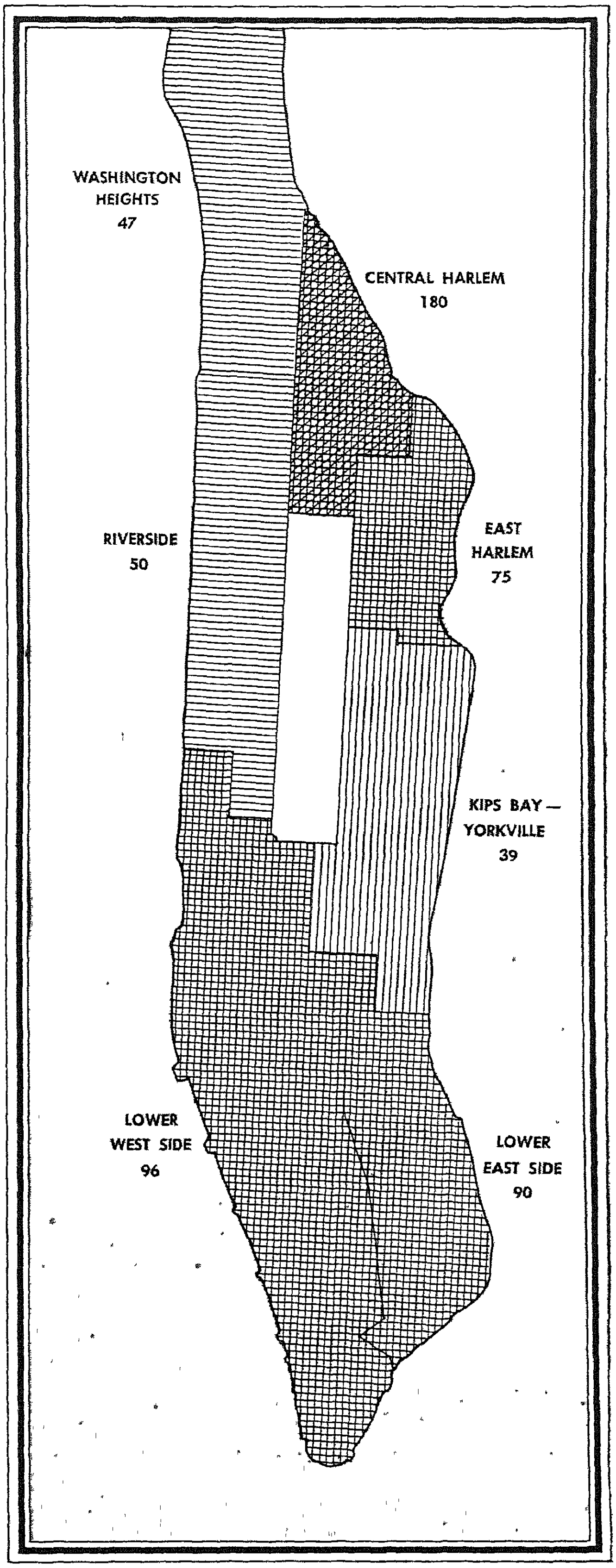
Meanwhile, occupied countries, although spared major epidemics such as were rife in Europe after the First World War, showed increased infant mortality and tuberculosis mortality, increased venereal disease rates and large-scale malnutrition. This was a striking demonstration that public health measures had succeeded in the fight against the old epidemic diseases, whereas the social diseases had followed closely the level of living conditions.

All these facts have contributed to increasing international recognition of the concepts of social medicine. The gradual realization of the potentialities of the scientific and social techniques available to national health administrations—linked with the growing sense of the community's responsibilities toward the underprivileged—have led to the broad social and humanitarian viewpoint embodied in the constitution of the World Health Organization.

Brock Chisholm, the noted Canadian psychiatrist, is presently Director General of the World Health Organization.



MEDIAN MONTHLY RENT for the inhabitants of the various parts of Manhattan Island is indicated in this map. Low-rent areas are Central Harlem, East Harlem, Lower East Side and Lower West Side. Kip's Bay-Yorkville area, in spite of relatively low median rent, includes one of Manhattan's high-rent districts. Blank spot in center of map is uninhabited Central Park.



DEATHS FROM TUBERCULOSIS, figured on the basis of the average rate per 100,000 people per year, are roughly correlated with rent. The highest tuberculosis death rates, and the lowest median rents, are found in Central Harlem, East Harlem, Lower East Side and Lower West Side. The high death rate of Central Harlem is complicated by the density of population there.

RADIOACTIVE ISOTOPES

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT	HALF-LIFE	TYPE OF RADIATION	TYPICAL APPLICATION
ANTIMONY	Sb	51	122	2.8d	B—, C	NUCLEAR STUDIES
			124	60d	B—, C	
			125	2 7y	B—, C	
ARGON	A	18	37	34d	K	STUDY OF GAS MIXING IN LUNGS
ARSENIC	As	33	76	26 8h	B—, C	NUCLEAR STUDIES
			77	40h	B—	PLANT DISTRIBUTION STUDIES
BARIUM	Ba	56	131	12d	K, e—	ION-EXCHANGE STUDIES
			140	12 8d	B—, C	NUCLEAR STUDIES
BISMUTH	Bi	83	210	5d	B—	SELF-DIFFUSION STUDIES
BROMINE	Br	35	82	34h	B—, C	CHEMICAL KINETICS STUDIES
CADMIUM	Cd	48	109	300d	K	NUCLEAR STUDIES
			115	2 33d	B—, C	
				43d	B—, C	
CALCIUM	Ca	20	45	180d	B—	BONE METABOLISM STUDIES
CARBON	C	6	14	5,100y	B—	STUDIES OF PHOTOSYNTHESIS
CERIUM	Ce	58	141	28d	B—, C	ION-EXCHANGE STUDIES
			143	33h	B—, C	
			144	275d	B—	
CESIUM	Cs	55	131	10 2d	K	ION-EXCHANGE STUDIES
			134	2y	B—, C	
			137	33y	B—, C	
CHLORINE	Cl	17	36	1,000,000y	B—	ION-EXCHANGE STUDIES
CHROMIUM	Cr	24	51	26 5d	K, C	FRICTION STUDIES
COBALT	Co	27	60	5 3y	B—, C	ANIMAL NUTRITION STUDIES
COLUMBIUM	Cb	41	95	35d	B—, C	NUCLEAR STUDIES
COPPER	Cu	29	64	12 8h	B—, B+, K, C	ANIMAL NUTRITION STUDIES
EUROPIUM	Eu	63	152	9 2h	B—	PHOSPHORESCENCE STUDIES
			154	7y	B—, C	
			155	2y	B—, C	
			156	15 4d	B—, C	
GALLIUM	Ga	31	72	14.1h	B—, C	NUCLEAR STUDIES
GERMANIUM	Ge	32	71	40h	B+	NUCLEAR STUDIES
				11d	B+, C	
			77	12h	B—	
GOLD	Au	79	198	2 7d	B—, C	TUMOR THERAPY
			199	3 3d	B—, C	NUCLEAR STUDIES
HAFNIUM	Hf	72	181	46d	B—, C	ION-EXCHANGE STUDIES
ILLINIUM	Il	61	147	3 7y	B—	STUDIES OF RARE EARTHS
			149	2d	B—, C	
INDIUM	In	49	114	48d	IT, e—	NUCLEAR STUDIES
IODINE	I	53	131	8d	B—, C	MEDICAL THERAPY AND DIAGNOSIS
IRIDIUM	Ir	77	192	75d	B—, C	NUCLEAR STUDIES
			194	19h	B—, C	
IRON	Fe	26	55	4y	K, C	BLOOD STUDIES
			59	44d	B—, C	FRICTION STUDIES
LANTHANUM	La	57	140	40h	B—, C	NUCLEAR STUDIES
MERCURY	Hg	80	197	64h	K, e—, C	SPECTROSCOPIC STANDARDS DEVELOPMENT
				25h	K, e—, C	STUDY OF DIURETICS
			203	51.5d	B—, C	
			205	51.5d	B—, C	
MOLYBDENUM	Mo	42	99	67h	B—, C	NUCLEAR STUDIES
NEODYMIUM	Nd	60	147	11d	B—, C	NUCLEAR STUDIES
			149	47h	B—, C	
NICKEL	Ni	28	59	15y	K, e—	METALLURGICAL DIFFUSION STUDIES
OSMIUM	Os	76	185	80d	K	NUCLEAR STUDIES
			191	32h	B—, C	
			193	17d	B—, C	
PALLADIUM	Pd	46	103	17d	K	STUDY OF ANALYTICAL CHEMISTRY
PHOSPHORUS	P	15	32	14.3d	B—	MEDICAL THERAPY
PLATINUM	Pt	78	197	18h	B—	
				3 3d	B—, C	
			199	31m	B—	
POLONIUM	Po	84	210	140d	A, e—, C	
POTASSIUM	K	19	42	12 4h	B—, C	STUDY OF DIFFUSION OF BODY FLUIDS
PRASEODYMIUM	Pr	59	142	19.3h	B—, C	NUCLEAR STUDIES
			143	13 8d	B—	
RHENIUM	Re	75	186	90h	B—	NUCLEAR STUDIES
			188	18h	B—, C	
RHODIUM	Rh	45	105	36h	B—, C	METALLURGICAL STUDIES
RUBIDIUM	Rb	37	86	19 5d	B—	STUDY OF EXCHANGE REACTIONS IN SOILS
RUTHENIUM	Ru	44	97	2 8d	K, e—, C	STUDY OF CANCER
			103	42d	B—, C	RADIATION SOURCE FOR GAUGES
			106	1y	B—	
SAMARIUM	Sm	62	153	47h	B—, C	PHOSPHORESCENCE STUDIES
			155	25m	B—, C	
SCANDIUM	Sc	21	46	85d	B—, C	NUCLEAR STUDIES
			47	3 4d	B—	
			48	44h	B—, C	
SELENIUM	Se	34	75	125d	K, e—, C	RADIATION SOURCE FOR GAUGES
SILVER	Ag	47	110	225d	B—, C	STUDY OF SOLUBILITY AND DEPOSITION
			111	7 5d	B—	
SODIUM	Na	11	24	14 8h	B—, C	BLOOD CIRCULATION DETERMINATIONS
STRONTIUM	Sr	38	89	55d	B—	NUCLEAR STUDIES
			90	25y	B—	EXPERIMENTAL TUMOR THERAPY
SULFUR	S	16	35	87.1d	B—	STUDY OF PROTEIN METABOLISM
TANTALUM	Ta	73	182	117d	B—, C	NUCLEAR STUDIES
TECHNETIUM	Tc	43	97	93d	K, e—, C	NUCLEAR STUDIES
			99	1,000,000y	B—	
TELLURIUM	Te	52	127	90d	IT, e—, C, X-ray	NUCLEAR STUDIES
				9.3h	B—	
			129	32d	IT, e—, C, X-ray	
				70m	B—, C	
			131	30h	IT, e—, C	
				25m	B—	
THALLIUM	Tl	81	204	2.7y	B—	EXCHANGE REACTION STUDIES, NUCLEAR STUDI
TIN	Sn	50	113	100d	K, e—, C	EXCHANGE REACTION STUDIES
			121	62h	B—	
			123	10d	B—, C	
TITANIUM	Ti	22	51	72d	B—, C	STUDY OF CONCENTRATIONS IN ALLOYS
TUNGSTEN	W	74	185	77d	B—	ELECTRO-DEPOSITION STUDIES
			187	24h	B—, C	ALLOY SEGREGATION STUDIES
YTTRIUM	Y	39	90	62h	B—	ION-EXCHANGE STUDIES
			91	57d	B—	NUCLEAR STUDIES
ZINC	Zn	30	65	250d	B+, K, e—, C	INSULIN STUDIES
			69	13.8h	IT, C	PLANT DISTRIBUTION STUDIES
				59m	B—	

STABLE ISOTOPES

ELEMENT	SYMBOL	ATOMIC NUMBER	ATOMIC WEIGHT
ANTIMONY	Sb	51	121
			123
BORON	B	5	10
CADMIUM	Cd	48	106
			108
			110
			111
			112
			113
			114
			116
CALCIUM	Ca	20	40
			44
CARBON	C	6	13
CHROMIUM	Cr	24	52
COPPER	Cu	29	63
			65
HELIUM	He	2	3
HYDROGEN	H	1	2
INDIUM	In	49	113
			115
IRON	Fe	26	54
			56
			57
			58
LEAD	Pb	82	204
			206
			207
			208
LITHIUM	Li	3	6
			7
MERCURY	Hg	80	198
MOLYBDENUM	Mo	42	92
			94
			95
			96
			97
			98
			100
NICKEL	Ni	28	58
			60
			61
			62
			64
NITROGEN	N	7	15
OXYGEN	O	8	18
POTASSIUM	K	19	39
			40
			41
SELENIUM	Se	34	74
			76
			77
			78
			80
			82
SILICON	Si	14	28
			29
			30
SILVER	Ag	47	107
			109
STRONTIUM	Sr	38	84
			86
			87
			88
TELLURIUM	Te	52	122
			123
			124
			125
			126
			128
			130
THALLIUM	Tl	81	203
			205
TIN	Sn	50	115
			116
			117
			118
			119
			120
			122
ZINC	Zn	30	64
			66
			67
			68
			70
ZIRCONIUM	Zr	40	90

THE AEC'S ISOTOPES

Presenting a complete list of the nuclear species available for the researches of peace

IN FEBRUARY this magazine published an article entitled "Tracers" which described the application of the nuclear species of atoms, or isotopes, to biological research. The advance of this method has been in large part due to the increasing availability of isotopes, notably as a by-product of the development and manufacture of atomic bombs.

In February the U. S. Atomic Energy Commission announced that all of the radioactive isotopes it had formerly made available at cost would now be given free to qualified cancer investigators On the opposite page is a complete table of the AEC's radioactive isotopes, compiled with the help of its Isotope Division at Oak Ridge, Tenn. On this page is a list of non-radioactive, or stable, isotopes which also may be obtained from the AEC.

With each of the radioisotopes is a brief tabulation of its significant characteristics The shorthand in which these are customarily written may be translated from the legend below. Some typical applications are also given Many of the isotopes obviously have more than one application. Among the most useful are the isotopes carbon 14, phosphorus 32 and sulfur 35, so common are these three elements through the entire range of chemical reactions

The application of isotopes is not limited to biological research. To name but a few other fruitful uses, isotopes have been of service in metallurgical and chemical research and in the study of the fundamental properties of matter. Isotopes have furthermore been applied in medicine. Some are useful in diagnosis, others in treatment. Radioactive phosphorus has been helpful in the treatment of the diseases polycythemia vera and chronic leukemia. Radioactive cobalt is a good substitute for radium in the radiation therapy of tumors. In brief, the most useful products that the Atomic Age has yielded thus far to man are the isotopes.

HALF-LIFE

- m: MINUTES
- h: HOURS
- d: DAYS
- y: YEARS

TYPE OF RADIATION

- A: ALPHA PARTICLE
- B−: NEGATIVE BETA PARTICLE
- B+: POSITIVE BETA PARTICLE
- C: GAMMA RAY
- e−: INTERNAL CONVERSION (GAMMA RAY EJECTS ELECTRON FROM THE ATOM)
- IT: ISOMERIC TRANSITION (NUCLEUS CHANGES FROM MORE TO LESS ENERGETIC STATE WITH EMISSION OF A GAMMA OR X-RAY)
- K: K-ELECTRON CAPTURE (NUCLEUS CAPTURES AN ELECTRON FROM INNERMOST SHELL OF THE ATOM)

AUREOMYCIN

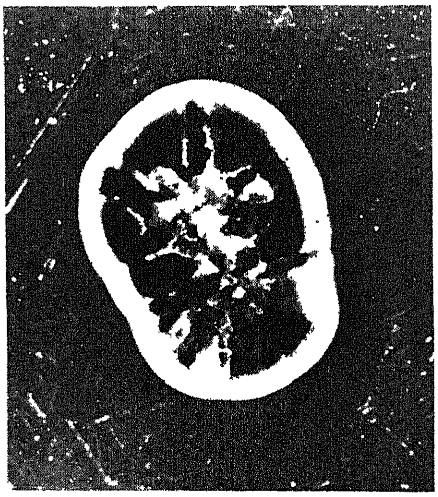
Far more versatile than penicillin or streptomycin, the new antibiotic has already been found effective against an astonishing variety of bacterial and viral diseases

by Leo and Dora S. Rane

THE PERFORMANCE of any new drug must be considered with reserve. The greater its promise, the more careful should be the evaluation of its results. This warning is a necessary preface to the following account of the clinical results achieved to date with a very spectacular performer—the antibiotic aureomycin. Introduced to medicine less than a year ago, it has now been tested in a great variety of infections by investigators in more than a score of hospitals. Taken all together, their reports indicate that even among the dramatic antibiotics aureomycin is unusual. It appears to attack a wider spectrum of diseases than any other drug yet discovered. Unlike the antibiotics penicillin and streptomycin, aureomycin has so far shown no sign of producing resistance among the bacteria it attacks. Most remarkable is the fact that it has been successful against certain virus and rickettsial diseases that have hitherto been invulnerable to any other chemotherapy.

In its clinical tests aureomycin has proved effective against many infections that had failed to respond or had become resistant to the sulfonamides, penicillin and streptomycin. It destroys both Gram-positive and Gram-negative bacteria (so named on the basis of whether they hold or fail to hold Gram's stain when prepared for microscopic examination). Aureomycin has shown notable activity against such bacterial diseases as acute undulant fever, peritonitis, urinary-tract infections, gonorrhea and the pneumococcal pneumonias. It has given exceptionally fine results in rickettsial diseases such as Rocky Mountain spotted fever, typhus and Q-fever (named for Queensland, Australia, where it was first discovered). The viral diseases that have responded to aureomycin are primary atypical pneumonia and a particularly recalcitrant venereal disease known as lymphogranuloma venereum. The latter was one of the earliest diseases treated with aureomycin, and the results were so successful that the investigators concluded: here for the first time is a cure for a virus disease in human beings.

The action of aureomycin is dramatic. The following is a typical case: A 13-year-old boy at camp began to feel ill eight days after his arrival. He complained of a headache and had a temperature of 102 degrees Fahrenheit. He was treated with sulfadiazine without effect. His temperature rose to 104 F., a rash appeared on his hands and feet and spread to his chest. He was taken to the hospital, acutely ill, on the fourth day, and his illness was diagnosed as the tick-borne disease Rocky Mountain spotted fever. This diagnosis was supported by the fact that his sister was suffering from the same disease and the boy remembered that he had removed several ticks from his body two days before coming to camp. The diagnosis of the disease was later confirmed by laboratory tests.



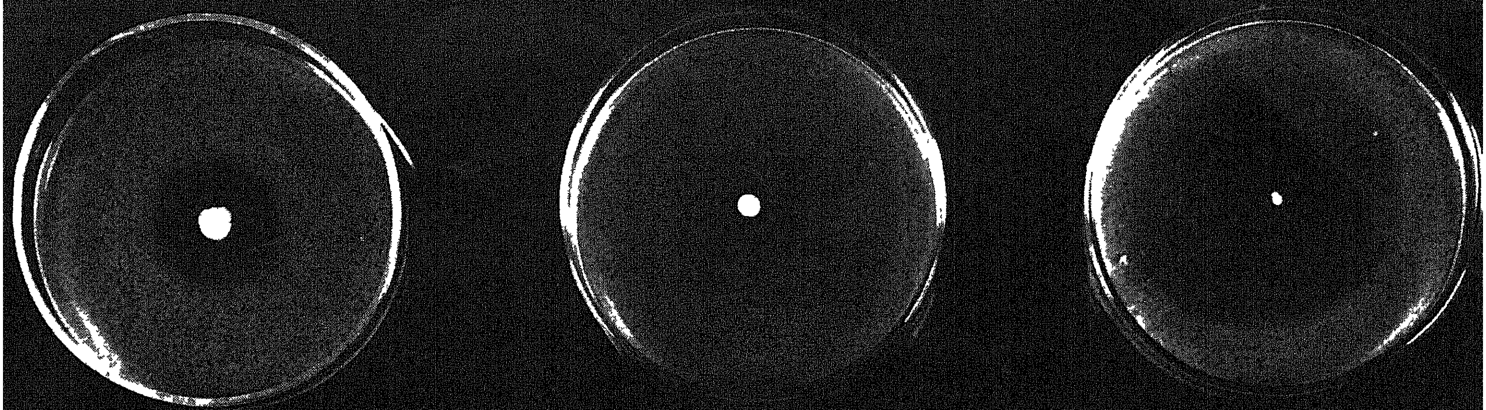
THE MOLD *Streptomyces aureofaciens*, **which yielded the antibiotic, is here shown growing in laboratory.**

Patients with Rocky Mountain spotted fever generally run a high fever for two to three weeks; if untreated, the disease is fatal in about 10 per cent of the cases, and complications develop in about 25 per cent. In this case aureomycin therapy was started immediately upon diagnosis of the disease. In 24 hours the boy's temperature began to drop; in 48 hours it was normal. On the fourth day of treatment his rash disappeared. Treatment was stopped on the fifth day, and on the seventh the patient was discharged from the hospital with no remaining traces of the disease.

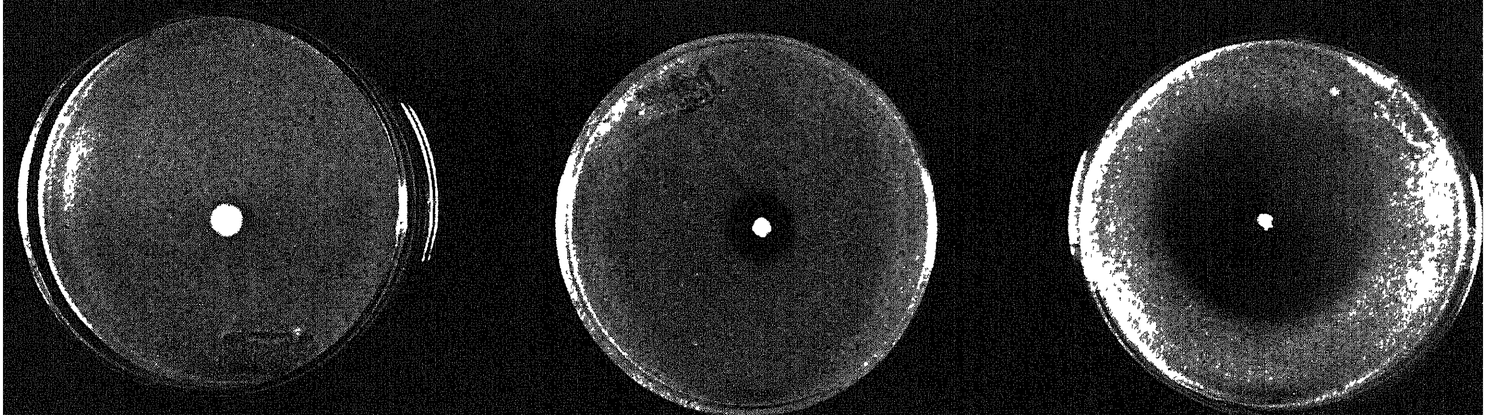
The mode of action of aureomycin is as yet completely unknown. While it is being given, the presence of the drug can be demonstrated in the patient's blood and urine; it is found in the urine more than 48 hours after treatment has stopped, even though it cannot then be shown in the blood. In the doses usually given—from one to four grams a day—it is not toxic to human beings. It is somewhat unstable in a water solution, but in the dried powder form it keeps indefinitely at normal temperatures. Not the least convenient of its properties is that for most diseases it can be taken effectively in capsule form instead of by injection, so that patients need not be hospitalized for treatment.

Aureomycin is derived from a mold belonging to the actinomycete group—the same family that produced streptomycin. The mold was discovered by the mycologist B. M. Duggar, a member of the research unit organized by Y. Subba-Row, the late, brilliant biochemist, in the Lederle Laboratories, a division of the American Cyanamid Company, at Pearl River, N. Y. The discovery was not an accident. It was the result of a long, deliberate search for new antibiotics in which Dr. Duggar tested thousands of strains of actinomycetes, isolated from samples of soil collected from many parts of the world. The most active of these many strains was one first known as A-377 and eventually named *Streptomyces aureofaciens*. The crystalline substance possessing antibiotic activity that was isolated from the culture medium in which the mold was grown was called aureomycin because of its golden color, not, as a London newspaper later said, "because it can be given by the mouth."

Aureomycin performed brilliantly against organisms in glass dishes, but some of its early tests in experimental animals were disappointing. Investigators of the U. S. Food and Drug Administration, who made some of the first experiments, concluded: "No outstanding usefulness for this antibiotic has been demonstrated by our animal investigations against the bacteria studied. The greatest promise for the drug lies in the

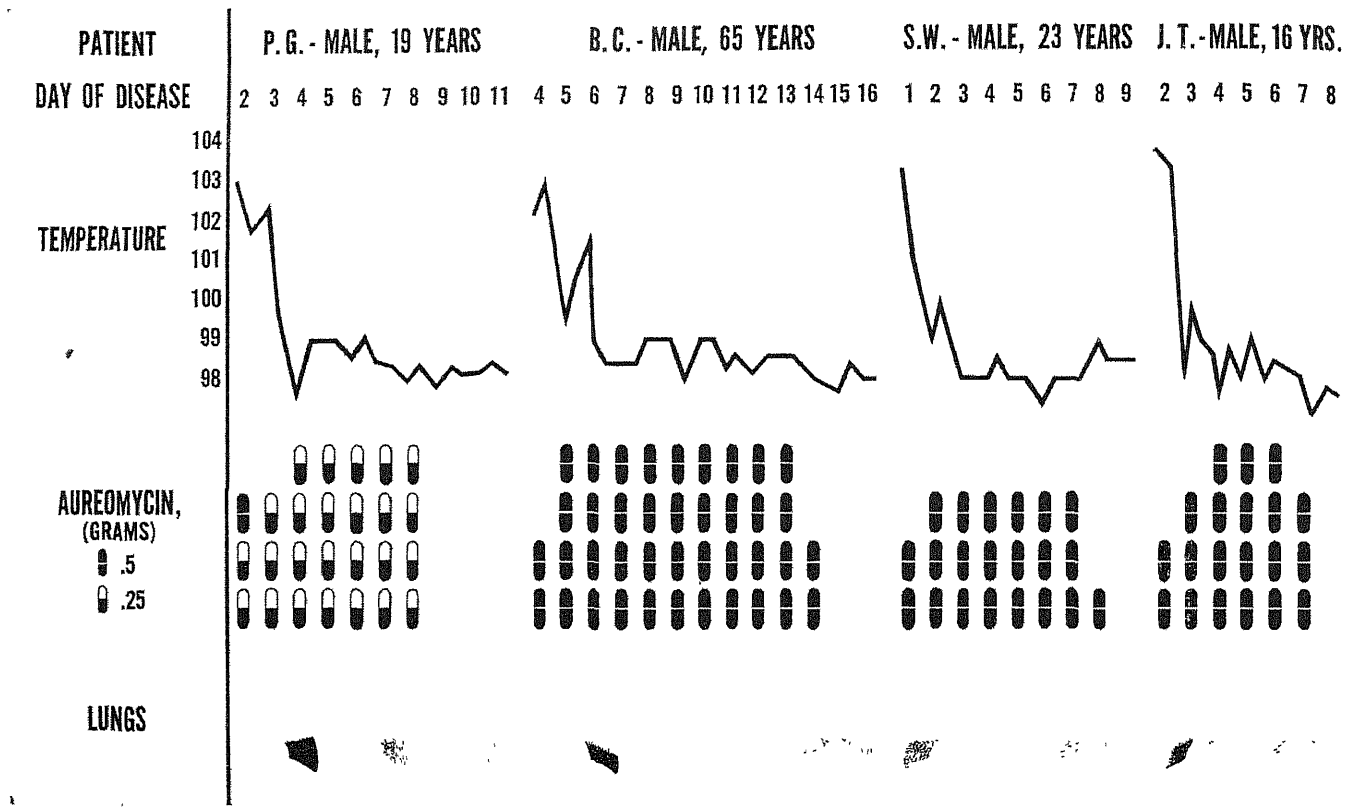


COMPARATIVE TEST of molds against *Staphylococcus aureus* bacterium in Petri dishes shows the powerful activity of aureomycin. Effect of mold (*center of dish*) is measured by cleared area around it, representing killed bacteria. From left to right above are molds of penicillin, streptomycin and aureomycin, respectively.

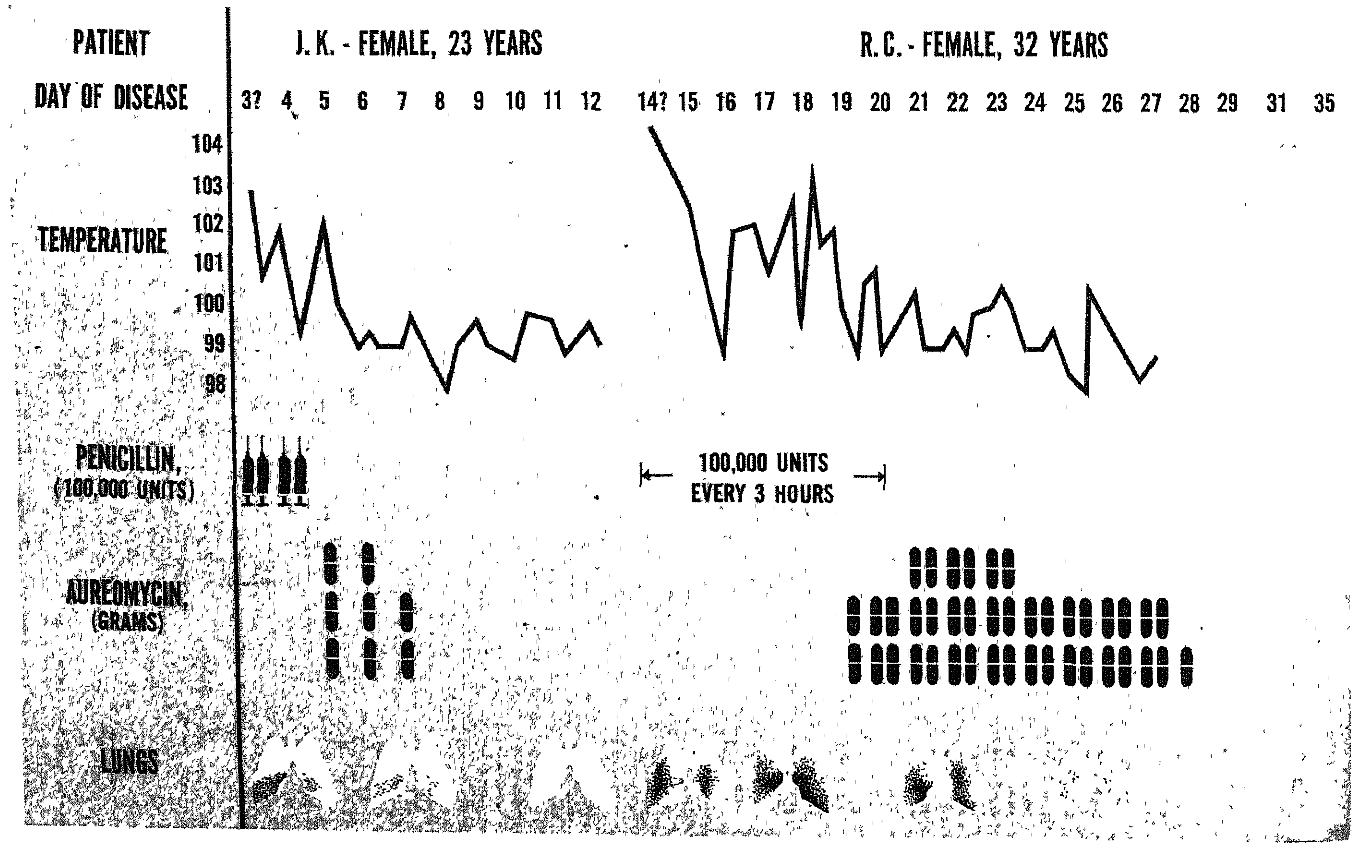


TUBERCULOSIS BACILLUS is subjected to same test with the three molds in this series. On glass, aureomycin seemed most active against tuberculosis, but in clinical tests it proved much less active than streptomycin. This test underlines the fact that an experimental drug does not always behave the same *in vivo* as *in vitro.*

SALMONELLA BACILLUS parasitic organism that causes food poisoning and other infections, is attacked by the same three molds. Aureomycin again shows the greatest activity. The organism is affected by penicillin (*left*) but apparently immune to streptomycin (*center*). These tests were made at the Lederle Laboratories.



CLINICAL CHARTS of patients show the dramatic results of aureomycin treatments. These four patients had pneumococcal pneumonia and were treated with varying amounts of the antibiotic by mouth. Their recovery is demonstrated by the rapid drop of temperature to normal and the quick clearing of the infected areas in their lungs. The aureomycin doses here ranged from three quarters of a gram to two full grams per day.



VIRUS TYPE of pneumonia known as primary atypical pneumonia also responds rapidly to aureomycin treatments. In these two cases, the patients had been treated first with penicillin, but after an initial drop in temperature their fever returned. Aureomycin finally eliminated the fever. One patient had run a fever for 18 days before aureomycin therapy began. The drug has been remarkably successful against infections of long standing.

treatment of certain viral and rickettsial diseases."

But aureomycin again proved a truism that has impressed all research workers in chemotherapy: human beings do not necessarily react in the same way as experimental animals. Drugs that work well in animals may fizzle out when tried in human patients. In contrast, aureomycin showed somewhat greater activity in human beings than in animals. In the case of undulant fever, for example, the antibiotic apparently was ineffective in animals but successful in human beings. And because its toxicity had proved to be negligible, the drug was even chanced in some human diseases without preliminary laboratory tests against the organisms involved, and some of these shots in the dark produced cures.

The clinical results of aureomycin thus far may be reviewed as follows.

Rickettsial Diseases

The rickettsias are infectious organisms intermediate in size between viruses and bacteria. Rocky Mountain spotted fever, an infection which has now spread to all parts of the U. S., is one of the most serious diseases produced by these organisms. The drug most commonly used to treat it has been para-aminobenzoic acid. This treatment, a survey has shown, reduces the duration and fatality rate of the disease, although complications developed in a substantial porportion of the cases (17 per cent), and the drug itself is somewhat toxic. Recently good results against Rocky Mountain spotted fever are reported to have been obtained by the new antibiotic chloromycetin. Aureomycin, however, appears to be a specific treatment for this disease. In a series of 25 cases, with patients ranging in age from one to 50, aureomycin produced the same rapid drop in temperature, disappearance of the rash and general clinical improvement that was noted in the case described earlier in this article. The average duration of treatment was four and a half days and the average hospital stay less than 10 days. No complications developed, and there were no signs of toxic effects except occasional short periods of nausea.

Q-fever, an acutely infectious disease now common on the west coast of the U. S. and Canada, is caused by a rickettsia that is spread primarily by cows and their milk. The infection lasts from eight to 15 days and produces a loss of appetite and severe physical discomfort. No therapeutic agent had been able to check this unpleasant fever. In a series of 11 cases, three of them serious, aureomycin produced astonishingly rapid recovery. Typical was the case of a 65-year-old man who, two days after onset of the disease, was admitted to a hospital with chills and fever, pains in the head and loins, extreme fatigue, nausea and a temperature of 104 F. He was given aureomycin, and in 24 hours showed considerable improvement. In 48 hours his temperature was normal, he was soon discharged from the hospital after an uneventful convalescence. Among the 10 other Q-fever patients in this group, all regained their appetites—the surest sign of improvement—within 48 hours after aureomycin treatment began, and lost their fever in 48 to 72 hours. In another group of five cases of long duration, the period of fever ranging from 23 to 77 days, four of the five patients responded promptly to aureomycin; the fifth, a 51-year-old man, failed to show appreciable improvement even with large doses of the drug.

The other rickettsial diseases against which aureomycin has shown dramatic activity are murine or endemic typhus and the relapsing form of epidemic typhus known as Brill's disease. Brill's disease, which is seldom fatal but often severely incapacitating, produces a rash and a high fever that reaches a crisis in from 10 to 16 days. A representative case was that of a 42-year-old man with Brill's disease who was treated with aureomycin on the sixth day of his illness. His fever subsided in 24 hours, and in 48 hours his rash had all but disappeared.

Viral Diseases

In this group of infections the effect of aureomycin has been altogether unprecedented. Lymphogranuloma venereum, a serious disease caused by a virus-like pathogen, results in swellings of the lymphatic glands of the groin, and in inflammation. Sometimes strictures of the rectum are produced. In a series of 35 acute and chronic cases of this disease, aureomycin stopped the infection and healed the swellings and inflammations; it could not, of course, correct the rectal strictures, which can only be treated by surgery. Many of these cases were followed up for two to four months after treatment with the drug, and they showed no relapse. The patients without strictures apparently were cured, while the others gained weight even when their strictures were not removed by surgery.

Aureomycin was also effective against the viral disease called granuloma inguinale, which produces ulcerative lesions of the groin. One patient who had extensive lesions from this disease had failed to respond to a variety of treatments, including antimonial compounds, X-rays and a long course of streptomycin, of which he received 100 grams over a period of 40 days. Treatment with aureomycin healed his lesions in nine days. Seven other patients with this disease, four of whom had also been treated with streptomycin without result, showed definite improvement after receiving aureomycin. If the promise

CULTURE A-377, the strain that produced the antibiotic, was the culmination of tests of thousands of soil samples from many parts of world.

held forth by these results is further substantiated, granuloma inguinale, a minor scourge in the Southern states, may cease to be a public health problem.

In primary atypical pneumonia, whose causative agent is suspected to be a virus, aureomycin at once showed very promising results. One of the earliest cases was that of a 41-year-old woman with a racking cough, a severe headache and a temperature of 103 F. who had been treated with a sulfonamide and with penicillin, of which she received 400,000 units daily for three and a half days, without effect. On the eighth day of her illness aureomycin therapy was started. Her temperature dropped to normal in 24 hours and stayed normal.

The effectiveness of the drug in primary atypical pneumonia was confirmed in several series of cases. In one series of 13 patients, all but one of whom were sick enough to be hospitalized, nine lost their fever in 24 hours, three in 48 hours and one in 72 hours after aureomycin therapy began. They had been sick for periods ranging from two to 21 days. Nine of the patients had previously been treated with sulfadiazine, penicillin, or a combination of both, without showing any clinical improvement. Another series of 10 cases yielded similar findings; one patient appeared moribund when treatment started, but she, too, recovered.

Bacterial Diseases

Among the bacterial infections, undulant fever, or brucellosis, has been particularly stubborn. Three varieties of the *Brucella* organism are known to produce the disease in human beings. Recently two of these, the milder ones, have been attacked successfully in clinical tests by combined treatment with streptomycin and sulfadiazine. The more malignant third form, *Brucella melitensis,* resisted every form of therapy attempted. In the laboratory, streptomycin seemed promising; in fact, in the glass dish and in infected chick embryos streptomycin appeared to be considerably more active against *Brucella melitensis* than was aureomycin. But streptomycin failed when it was tried in human beings.

Aureomycin succeeded. One of the most remarkable of the many cases in which it has been used was that of a young housewife who developed the malignant type of brucellosis six days after giving birth to a baby. She lost weight and strength steadily for six months thereafter, and her temperature rose as high as 105 F. Five days after aureomycin therapy was instituted, her fever and symptoms subsided completely. The recurrences which are so characteristic of this disease seem to be all but eliminated by aureomycin. In a series of 24 cases which were followed up after recovery, 82 cultures of the patient's blood were taken over a period of three months, and in only three cases did the cultures suggest bacteriological symptoms of relapse.

The list of other bacteria attacked by aureomycin is long. It has been used successfully against the hemolytic (red blood cell-dissolving) *Staphylococcus aureus* In one case, an infant in whom the infection had spread, despite treatment with penicillin, over a considerable area of a lung, aureomycin cleared all but one small area. In another, the drug healed a brain abscess involving the same organism.

In urinary-tract infections, which often are caused by a combination of two or more bacteria, aureomycin has produced high percentages of cures—seven out of eight in one series, all 10 cases in another, 11 out of 15 in a third. Many of these patients had previously been treated unsuccessfully with sulfonamides, penicillin and streptomycin. Against urinary-tract infections of long duration and with marked anatomical changes, aureomycin was less effective, in a group of 16 cases of this character it produced temporary relief in two thirds of the cases but no permanent cures. Most of these patients, incidentally, were not hospitalized during treatment with aureomycin.

Because of the effectiveness of penicillin against the pneumococcal pneumonias, aureomycin has been tested in relatively few cases of this infection, but it has performed well in the tests made. In one instance a patient with pneumococcal meningitis which had become resistant to sulfadiazine, penicillin and streptomycin recovered rapidly upon receiving aureomycin.

The antibiotic has been especially encouraging against various eye infections, both bacterial and viral. It has successfully treated diseases of the eyes due to pneumococci, staphylococci, the influenza bacillus, the diplobacillus of Morax-Axenfeld, Friedlander's bacillus, the bacillus known as *E. coli*, and viral infections such as herpes, follicular conjunctivitis and inclusion conjunctivitis. It may also be effective against trachoma, for the virus of that disease is similar to that of inclusion conjunctivitis. And, while too few cases have yet been reported to justify a definite conclusion, aureomycin appears to offer promise against the epidemic eye infection called shipyard disease.

In the venereal diseases gonorrhea and syphilis, aureomycin may turn out to be second to penicillin, most useful in cases resistant to penicillin or in patients sensitive to that drug. In a group of 148 cases of active and acute gonorrhea, aureomycin proved as satisfactory as penicillin when both were taken orally, but less effective than the earlier antibiotic administered by injection. The results of aureomycin against syphilis are still uncertain, but it has shown definite ability to kill the spirochetes causing this disease

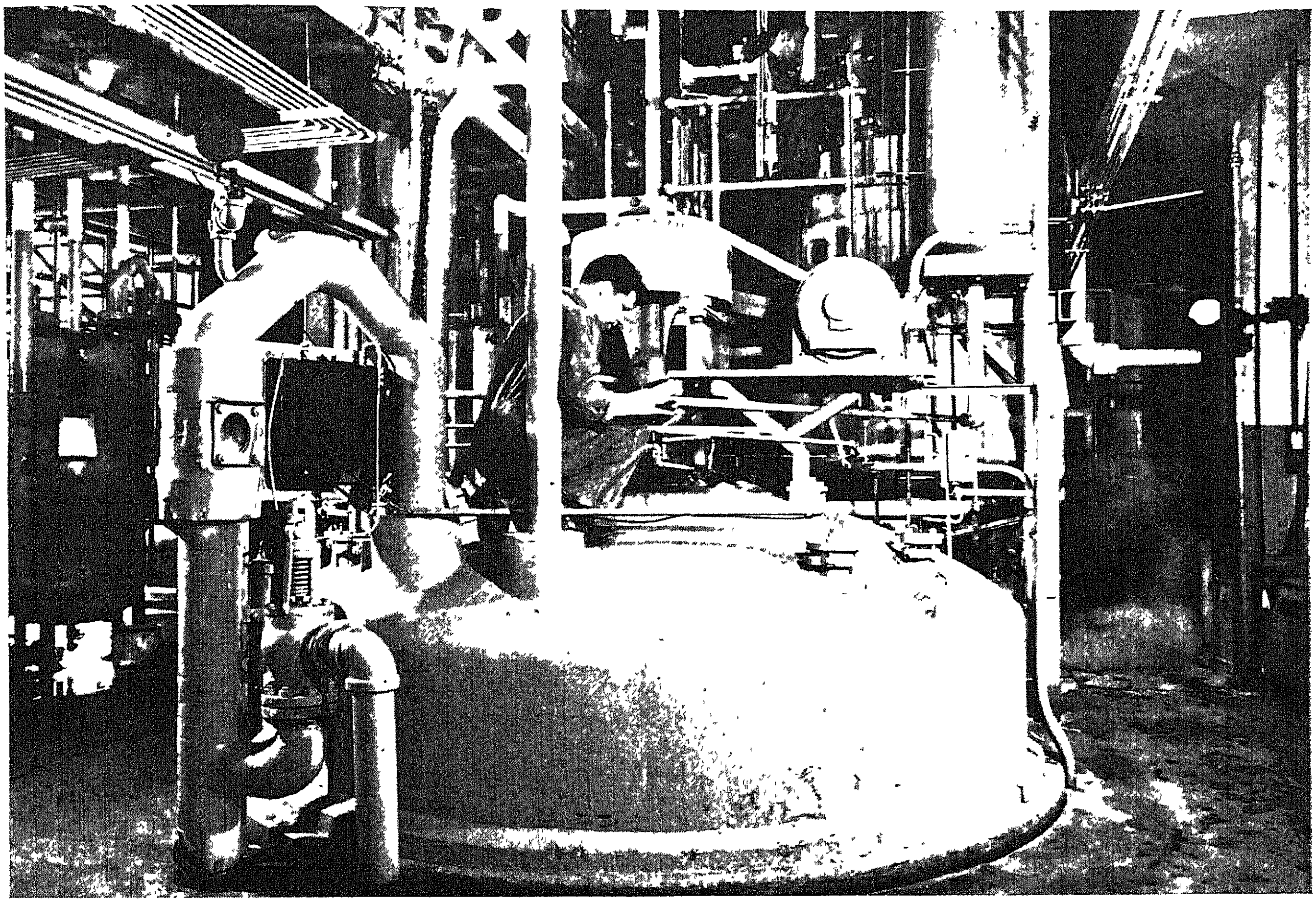
Aureomycin is by no means to be considered a cure-all. It has shown no activity against such virus diseases as poliomyelitis or influenza and it has offered little hope thus far against tuberculosis, typhoid fever and certain other major diseases. But its low toxicity, carefully determined by every conceivable type of test, invites clinical experiments. In the laboratory, animals show high tolerance to the antibiotic: even the extremely large dose of 2,500 milligrams per kilogram of body weight, when given orally to mice, kills only five per cent of the mice. In clinics, prolonged treatment of patients ranging in age from three to 65 has produced no ill effects. Unusually large doses of aureomycin may sometimes result in looseness of the bowels (but not true diarrhea), and some patients on smaller doses occasionally have felt nausea or vomited, but these effects could not always be ascribed to the antibiotic.

Thus physicians have felt safe in expanding the use of the antibiotic even to infections where there has been no previous suggestion that it may be effective An instance is reported of a physician who was treating a case of subacute bacterial endocarditis with penicillin, the drug of choice for this dangerous heart disease, until he was compelled to discontinue the drug because the patient became sensitive to it. Shifting to aureomycin, the physician continued this treatment for 11 weeks, and the patient now appears to be well.

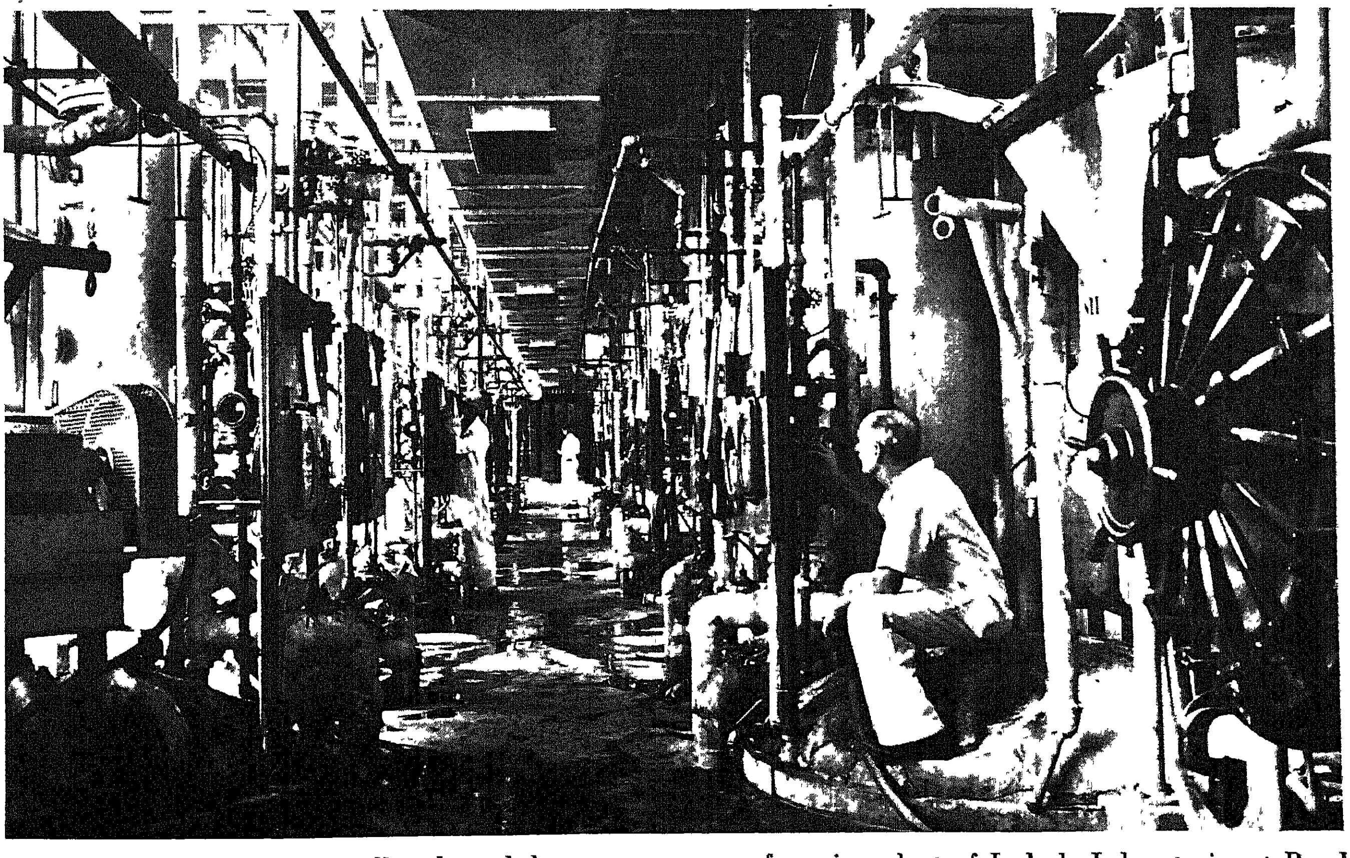
One of the most striking cases of all was that of a 65-year-old man who was admitted to a hospital with a strangulated hernia and a severe, generalized peritonitis (infection of the abdominal membrane) which upon operation was found to be due to a ruptured appendix. For five days the patient was given penicillin and streptomycin, but he did not do well. His wound failed to heal, and he ran a high temperature. On the sixth day he eviscerated and was returned to the operating room, where his entire peritoneal cavity was found heavily infected. The patient was treated with aureomycin as a desperate resort. In 48 hours his temperature dropped from 105 F. to normal. He was discharged from the hospital 13 days later.

Case reports such as these have had a considerable impact on the medical profession. And clinicians no longer ask what aureomycin can do; their question now is. How much more will it do?

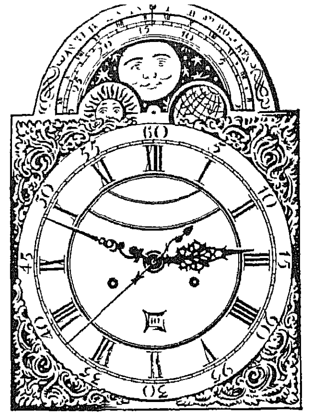
Leo Rane, formerly a bacteriologist at the Harvard Medical School, is a research consultant for Lederle Laboratories. Dora S. Rane, his wife, is a writer on scientific subjects.



PRODUCTION of aureomycin takes place in huge vats such as those developed for manufacture of penicillin and other antibiotics. Seen here is top of a tank which extends to the floor below. End product is yellow powder.



MOLD IS GROWN first in small tanks and then transferred to large ones. Aureomycin is produced in the manufacturing plant of Lederle Laboratories at Pearl River. The drug is now generally available to physicians.



SCIENCE AND

The Blackett Book

A HEAVY cannonade of criticism has greeted P. M. S. Blackett's *Fear, War, and the Bomb,* which was published in the U. S last month (and debated in the March issue of this magazine).

In an article titled "Playing Down the Bomb," in the April issue of *The Atlantic,* I. I. Rabi, chairman of the Columbia University physics department, attacks the book as an "extraordinary piece of special pleading" Rabi declares that Blackett, in comparing atomic explosives with the bombs dropped on Germany, neglected the saturation effect made possible by atomic bombs. Rabi disputes Blackett's estimate of the importance of atomic energy and its possible role in enabling the U.S.S.R. to catch up industrially with the U. S. He says. "Professor Blackett did not work on the atomic bomb project during the war, and his professional interest in recent years has not been primarily in nuclear physics. There are many points in the book which show that his thinking in this field is that of an outsider. . . . Atomic power is not around the corner." Rabi also criticizes Blackett's suggestion that a general disarmament cannot be negotiated until Russia has its own bombs. "This," he says, "is exactly the kind of dreaded armed truce American scientists have sought to avoid."

The *Bulletin of the Atomic Scientists* devotes a third of its latest issue to reviews by Edward A. Shils of the University of Chicago sociology department, Chairman Brien McMahon of the Joint Congressional Committee on Atomic Energy; Philip Morrison of the Cornell University physics department; and M. Marinin, a Russian writer whose favorable review of Blackett's book originally appeared in *Pravda.*

Shils, who has been active in support of the Baruch plan, denounces Blackett's volume as an apology for Soviet policy "which states a defense for the Soviet Union position . . . much better than any Soviet delegate has ever stated." Shils concedes that the book contains "some very impressive pieces of analysis. . . . It is therefore necessary that this gift to Soviet propaganda be studied and understood. . . . It cannot be refuted or dismissed by self-righteous clichés."

Senator McMahon remarks that he is not reassured but frightened by Blackett's data "debunking" the bomb "Taking 400 bombs as the least quantity needed to duplicate the ruin visited upon Germany," he observes, "how can we conclude that atomic energy is an exaggerated menace? Must we not conclude, rather, that 400 bombs is a terrifyingly small number?"

Morrison, who is in general agreement with the British physicist's thesis and conclusions, adds two footnotes One is a calculation of the number of atomic bombs that would be required to equal the damage done by the German army in Russia. He arrives at an estimate of 800 to 1,200 Allowing for interceptions, delivery of these would require "the launching of many more than a thousand under present conditions." Concludes Morrison. "A major war will not be a three-week aerial expedition." His other footnote concerns Blackett's charge that the dropping of the bomb on Hiroshima was timed to occur before the scheduled entrance of the U.S.S.R. into the war against Japan. Morrison, a staff physicist at the Los Alamos bomb laboratory during the war, recalls that August 10 had been set as an absolute deadline for completion of the bomb, to be met regardless of cost.

The Mexican physicist Manuel Sandoval Vallarta, former member of the United Nations Atomic Energy Commission, terms the volume "an absorbing book." He disagrees, however, with Blackett's assessment of the bomb and his political analysis. Writing in *Physics Today,* Vallarta declares his conviction that the atomic bomb is qualitatively a new weapon and that acceptance of the U. S. proposals for control of atomic energy would have speeded up its development for peaceful purposes.

FAS Proposals

A PROPOSAL that the United Nations take over world-wide distribution of isotopes as a start toward breaking the atomic-control deadlock has been made to the UN by the Federation of American Scientists.

Four countries—the U. S., Canada, Great Britain and France—already are turning out pile-produced isotopes. Sweden, Norway, India and perhaps the U.S.S.R. also are expected to be producing them soon. The FAS predicts that isotopes will therefore become a substantial item of international trade. It suggests that the UN should set up an agen-

cy to assist in publication of research with isotopes and to help smaller countries and laboratories obtain supplies.

Russian Bombs?

WERNER HEISENBERG, the leading German physicist and head of the abortive German wartime atomic-energy project, told the press last month that he is "almost certain" that Russia has started production of atomic bombs at two Siberian centers. He named the centers as Atomgrad, a new city, and Uchta. Both are near Lake Baikal, an area known to contain uranium ores.

Heisenberg is now living at Gottingen in the British zone of Germany. He did not disclose the source of his information. He also said that the U.S.S.R. has made "dangerous discoveries" in death rays.

Uranium Strikes

TWO new potentially important finds of uranium have been made, in France and in Canada.

The French strike, according to Frederic Joliot-Curie, director of the French Atomic Energy Commission, will make France self-sufficient in uranium. France has had to depend on imports or very low-grade domestic ores. Its new find is a vein of pitchblende bearing 20 per cent uranium near St. Sylvestre, a village in central France. It was discovered by geology students on a field trip. Commercial-scale mining operations have begun.

The Canadian discovery, on the Lake Superior shore 70 miles from Sault Ste. Marie, was made late last fall, shortly before winter ended prospecting activities. Although it is not yet certain that the deposit is of exploitable dimensions, hundreds of prospectors are waiting to rush the site as soon as the ice breaks up. Samples of its pitchblende have assayed as high as 59 per cent uranium.

Fission Threshold

INFORMATION about a critical property of thorium and uranium—the minimum neutron energies required to make them undergo fission—has just been declassified and published with the authorization of the Atomic Energy Commission. Thorium, it is disclosed, must be struck by neutrons with energy of at least 1.1 million electron volts (mev) to undergo nuclear fission. The fission of U-238, the common isotope of uranium, requires neutrons of 1 mev.

These data were determined eight years ago. The measurements, made by

J. E. Hill, W. E. Shoupp and F. W. Stallman at the Westinghouse Research Laboratories, played a part in shaping the direction of development of materials for the atomic bomb. Physical theory and approximate earlier measurements had indicated that the thorium and U-238 thresholds were in the fast neutron range. The Westinghouse study confirmed this assumption and helped to clinch the decision to concentrate on U-235 and plutonium as the materials for production of a chain reaction. U-235 and plutonium are fissionable by slow neutrons with energies of a few thousand electron volts.

Publication of the thorium and U-238 thresholds suggests that the AEC believes there is no possibility of using natural thorium or U-238 directly in a chain reaction. Presumably nuclear piles using these materials would be impractical either because the energy thresholds are entirely too high, or because the thorium and U-238 cross sections (frequency of effective hits by bombarding neutrons) are too low, or for both reasons.

AEC Board

THE Atomic Energy Commission has established a permanent Personnel Security Review Board such as was recommended by last year's temporary review board under former Supreme Court Justice Owen J. Roberts. The Board will review AEC clearance procedures and serve as a final court of appeal in AEC clearance cases. The three members of the board are Charles Fahy, former U. S. Solicitor General, chairman, Arthur S. Flemming, president of Ohio Wesleyan University and former Civil Service Commissioner; and Bruce D. Smith of The United Corporation.

Biological Warfare

AFTER an absence of two years, biological warfare is back on newspaper front pages. *Peace or Pestilence*, a book by Theodor Rosebury, Columbia University bacteriologist and co-author of the widely publicized biological warfare report in the *Journal of Immunology*, is scheduled for publication by Whittlesey House this month. Meanwhile, retiring Defense Secretary James Forrestal and Major General Alden H. Waitt, chief of the Chemical Corps, which has had charge of Army biological warfare research, have made public statements on the subject. Both described as "fantastic" such reports as the reputed ability of an ounce of botulinus toxin to kill every man, woman and child in North America. They deny that any "biological super-weapons" exist. They declare, however, that bacterial warfare is an entirely practicable possibility.

The U. S. has no stockpiles of germ weapons, General Waitt says, and "it does not follow that if the enemy uses gas or biological warfare that the U. S. will use them." But the U. S has a biological warfare research program "with the best scientists in the world working on the problem," and it is "better prepared" than any potential enemy.

Secretary Forrestal indicates that methods of dispersing germ agents are the principal technical problem in biological warfare. He discloses that Federal civilian agencies, as well as the armed services, have been brought into the planning of defenses against food- and water-borne disease agents.

Energy Resources

THE widely held belief that the U S has sufficient coal for some 2,000 years is disputed in a new review of world energy resources. The review, prepared by Eugene Ayres of the Gulf Research and Development Company, holds that we have only 92 to 292 years' supply. He arrives at this estimate on the basis of expected increases in the future demand for coal and of impending large-scale production of synthetic liquid fuels from coal. Conversion of coal to gasoline entails the loss of a large fraction of its energy.

If the world demand for energy continues to rise as it has since the beginning of the Industrial Revolution, Ayres predicts, use will eventually far outstrip possible new discoveries of underground fuels, including uranium. New sources of energy will then have to be found or consumption curtailed.

The way out of the dilemma, in Ayres' opinion, lies in the greater use of replenishable sources of energy. He suggests that the energy now consumed could be doubled within a century by exploiting these sources, of which the most important is solar energy. Others are water power and vegetation, which could be converted to gas, gasoline or alcohol, or burned as is. The use of solar energy for heating homes and buildings, currently under trial at the Massachusetts Institute of Technology, will, he thinks, be economically significant within a decade.

Malaria

A MAJOR offensive against malaria is to be launched this summer by the World Health Organization, International Children's Emergency Fund, and the Food and Agriculture Organization.

WHO teams have been in Greece for a year, battling malaria with DDT and synthetic antimalarials. Demonstration units have just arrived in Indo-China and Siam. Similar teams will be sent in a few months to Burma, Ceylon, India, Indonesia, Malaya, Pakistan and Yugoslavia. In addition, other agencies are active elsewhere; the Italian Government in

Italy, the International Health Division of the Rockefeller Foundation in Sardinia, the British Government in Cyprus, the U. S Public Health Service in the Philippines, and a variety of local and outside health agencies in Africa and Latin America

DDT has now made it possible to control the disease. In southern Greece, three years of DDT treatment by UNRRA and WHO to eradicate malaria-bearing mosquitoes have reduced the malaria incidence from one million to 50,000 a year at an annual cost of 30 cents per person

German Science

GERMAN science is being reconstituted along "extremely undemocratic" lines substantially similar to those before the war, three British scientists charge. They are Sir Robert Watson-Watt, radar pioneer and chairman of the British Association of Scientific Workers, J. G Crowther, secretary of the Association, and R. C Murray of the Institution of Professional Civil Servants. They visited Germany last spring as delegates of their organizations.

The Max Planck Society for the Advancement of Learning draws their heaviest fire The Planck Society was set up to take the place of the Kaiser Wilhelm Society, which operated the principal German research centers (the so-called Kaiser Wilhelm Institutes) and which was dissolved by Allied authorities.

The Planck Institutes seen by the delegation had received priorities for building materials and were physically well off. Facilities of the six pure-science institutes at Gottingen compared favorably with the Cavendish Laboratory at Cambridge. The three British scientists said that the funds for these establishments are being supplied almost exclusively by large industrial firms which occupied a key place in the Nazi war economy.

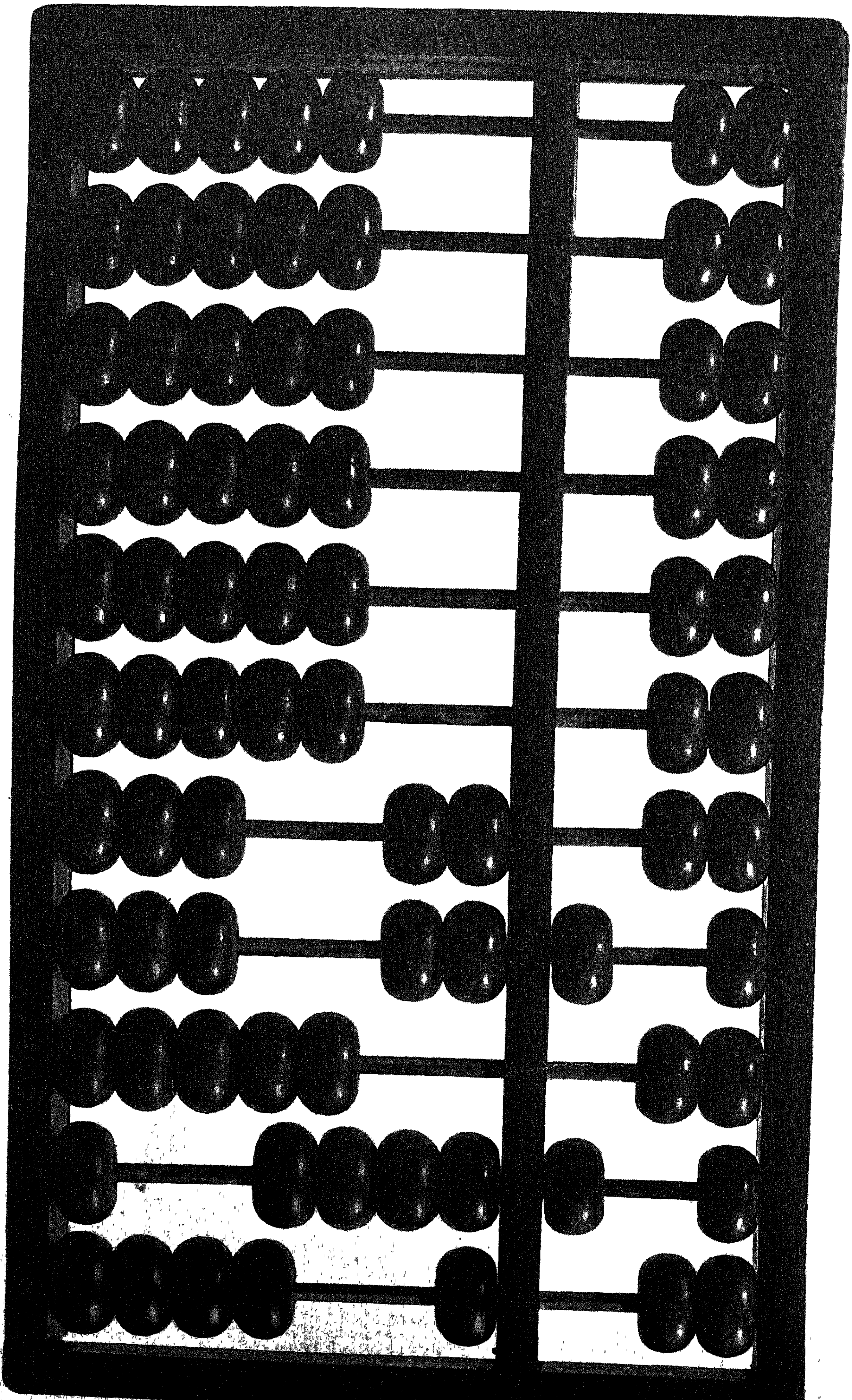
"At the factories of I G. Farben Industrie at Leverkusen and Elberfeld," the report asserted, "the organization of research seems to be substantially unchanged from what it must have been before and during the war. . . . Those German scientists in the British zone on whom the main responsibility of reorganizing science falls are busy doing this along lines that are in all respects identical in form with those which enabled science to be so easily perverted by the Nazis."

Meetings in May

AMERICAN Society of Mechanical Engineers. New London, Connecticut. May 2-4.

Acoustical Society of America. New York City May 5-7.

International Congress on Rheumatic Diseases. New York City. May 30-June 3.



MATHEMATICAL MACHINES

Some measure, others count. The latter, with which this article is principally concerned, are the focus of much feverish activity, not all of it purely scientific

by Harry M. Davis

A NEW revolution is taking place in technology today It both parallels and completes the Industrial Revolution that started a century ago. The first phase of the Industrial Revolution meant the mechanization, then the electrification, of brawn. The new revolution means the mechanization and electrification of brains.

The 19th-century revolution was based on the transformation and transmission of energy—call it what you will: calories, ergs, horsepower-hours, foot-pounds, joules, British thermal units, kilowatt-hours.

The 20th-century revolution is based on the transformation and transmission of information: a number, a letter of the alphabet, a dark or light spot in a picture, an "on" or "off" signal, a decision between "yes" and "no"; a judgment as to "more" or "less"; a logical discrimination among "and," "or," and "neither." These are the raw materials and the products of "information-processing systems" that are assuming many of the human functions of calculation, communication and control.

How far has this revolution gone? Much of it is already taken for granted in our daily lives—in the shape of radio, television, telephone dial systems. Other phases affect us less obviously—robot pilots for aircraft; electronic navigation systems; automatic controls in factories; the many kinds of radar. All such devices have functions that are comparable, in one way or another, with the processes of human thinking.

But the machines that above all others deserve the title of "brains" are the electronic computers which easily solve problems so intricate and laborious that they stagger the most patient mathematician. They read, they write, they do arithmetic—all at rates ranging from a thousand to a million times faster than the human eye, mind, and hand.

THE ABACUS was perhaps the earliest mathematical machine. The number indicated by the Chinese abacus on the opposite page is 27,091.

Do They Really Think?

To the question, "Do these machines really think?" one can get various semantic interpretations of the words "really" and "think," including the rejoinder, "How much do people really think?" Calculator designers and psychologists seem to gain more respect for the human brain the more they learn about its mechanical competitors. In strictly electrical and chemical terms, the human brain is the most efficient of computing machines, although it is also the slowest. It does not need kilowatts of power to energize its nerves, nor blowers to ventilate it, the electrical brains definitely emit more hot air. Warren McCulloch, the neuropsychiatrist, has pointed out that if a calculator were built fully to simulate the nerve connections of the human brain, it would require a skyscraper to house it, the power of Niagara Falls to run it, and all the water of Niagara to cool it.

"The more I deal with these machines," said one expert, "the more impressed I am with how dumb they are." They do nothing creative. They can only follow instructions, which must be reduced to the simplest terms. If the instructions are wrong, the machines go wrong.

On the other hand, the machines are not subject to distraction. They concentrate all their faculties on the problem at hand. They can do a complicated calculation in less time than it takes a human being, for example, to react to a red traffic light by signaling his right foot to move from gas pedal to brake. Thus they can take over an immense burden of mental labor, handling mathematical and logical data in quantity just as the assembly lines have converted hand labor to mass production.

Claude E. Shannon of the Bell Telephone Laboratories aptly answered the "do they think" question when he said that the performance of the newest machines "will force us either to admit the possibility of mechanized thinking or to further restrict our concept of thinking." Shannon made this remark at the March meeting of the Institute of Radio Engineers, where he explained how the computers could be taught to play an adequate, though not brilliant, game of chess. Against the greater inventiveness of the human chess master, the machine, with its built-in procedures for choosing the next move, would have the advantage of high-speed operation, freedom from errors, and freedom from laziness.

A New Industry

Already the building and operating of automatic brains is becoming a big business. The electronic brains cost from $50,000 to $1,000,000 each, and there are eager waiting lists of customers—airplane manufacturers, insurance companies, statistical services and, above all, the various agencies of the Government. The census of 1950, it is hoped, will be the first to be analyzed by all-electronic computers, extracting a wealth of information about the nation's economic life that has never before been refinable from the statistical ore despite the use of punch-card tabulating machines.

The electronic machines are versatile. Nuclear physicists in Chicago send prob-

lems to Aberdeen, Md., for processing on the famous Eniac computer. The International Business Machines Selective Sequence Calculator a streamlined roomful of tubes and relays behind plate glass on New York's 57th Street, is more than an advertising showplace. While shoppers and art-gallery goers on the fashionable street glance in, the machine silently works out problems such as the motions of the moon or the control of guided missiles.

IBM has already incorporated some of the best circuits from this big machine into a little one, the size of two filing cabinets, neatly packaged in crackle-finish gray metal and mounted on casters so that it can be installed near the electric socket of any business office. Ten times faster than the previous IBM commercial calculating punches, the electronic Type 604 is now coming off the production lines in quantity.

But these instruments are only the pioneers of the new age of electronic thinking. At the computer sessions of the American Institute of Electrical Engineers in February and of the Institute of Radio Engineers in March, it became clear that every calculator now in operation will soon be as outdated as an earphone-and-crystal radio compared with the frequency modulation-television models of 1949. The older machines, however, will not become obsolete, because problems exist suitable for every type to handle.

Fantastic new computers, geared not to split-second but to split-microsecond speed, are being rushed to completion. The Moore School of the University of Pennsylvania, birthplace of the Eniac, is building a machine called Edvac which has a far more capacious memory and greater versatility. This it is doing without the further aid of the Eniac's principal designers and the Edvac's original conceivers, John Mauchly and J. Prosper Eckert, Jr., who have gone into business with the Eckert-Mauchly Computer Corporation Occupying two floors in a Philadelphia building, Eckert-Mauchly is testing a pair of computers known as Binac. Eckert-Mauchly also has contracts for six more elaborate machines known as Univac, to cost about $200,000 each, for government, industrial, and commercial use.

At Princeton, N. J., in a special computer building belonging to the Institute for Advanced Study, John von Neumann and other eminent mathematicians have been at work more than two years on a colossal computing device that is still some distance from completion. This is the machine that has been described by Vladimir Zworykin, research director of the Radio Corporation of America (which is cooperating in the project) as a future "world weather model." It might be set up to simulate every weather-making force and have these forces work upon one another a bit faster than in nature, thus tomorrow's weather could be read off today and not, as would be the case if every factor were taken into account by present methods, a year from now. But Dr. von Neumann is just as much interested in putting the machine to work on questions of atomic physics and economic statistics.

Meanwhile the Raytheon Manufacturing Company of Waltham, Mass., previously best known for manufacturing the magnetron tube of microwave radar, has accepted a big Government contract for a computer comparable with the Univac. Harvard University, having shipped its Mark II computer to the Naval Proving Ground at Dahlgren, Va., is up to a Mark III. The Massachusetts Institute of Technology has its "Project Whirlwind" for the construction of electronic brains needed for military purposes.

British scientists are active in the picture, too. They have a proud tradition in the field, for the Englishman Charles Babbage more than a century ago outlined the essential features of modern computers with his plans for a "difference engine." Advanced computers are now under construction by four British laboratories.

Not all of this activity is on the surface, nor is the picture one of uniform sweetness. There are military secrets and there are commercial secrets. Behind the scenes one senses intense rivalry and competition, with privately voiced charges of unfair publicity claims and pirated inventions, and hints of patent litigation to come. These are the symptoms of a big new industry in the making, with people fighting for their place on the ground floor.

What is at stake in the competition can be understood from a simple comparison. Some of the new machines under development will have the basic ability to carry out the multiplication of two 10-digit numbers in approximately a thousandth of a second The same task would take five minutes (about 300,000 times as long) for a man with pencil and paper. The machine is equivalent to about 25,000 operators of desk computing machines.

Digital *v.* Analogue

There are two families of computers—the digital and the analogue. Those discussed above are of the digital type. It is with these that this article is primarily concerned. But the analogue computers came first; the celebrated "mechanical brain" at M.I.T., for which Vannevar Bush gained fame two decades ago, was an analogue machine. Radar and gun directors leaned heavily upon them, and they will continue to be important in many ways. So let us examine these machines before clarifying the distinction between analogue and digital computers and dissecting the latter

The speedometer in your automobile is a simple example of the analogue computer. In proportion to the speed of the drive shaft, a centrifugal force is set up which moves a needle to the appropriate place on the "miles per hour" dial This is an operation of differential calculus—a stationary needle position on the dial displays the rate of change in the position of the car.

The gears of your car, or of your watch, also do arithmetic· they multiply and divide, although, of course, the multiplier is fixed by a built-in gear ratio. The differential, between the rear wheels, is what its name implies, a mechanical subtracting machine, any extra speed gained by one wheel being subtracted from the other. All these ideas are actually used in mechanical computing machines of the analogue type, among their components are gears and cams and differentials.

Bush's "differential analyzer" solved problems in calculus. Different elements of the machine were set for various parts of the equation, all being geared together so that the only answers to come out would be the ones that were true to the equation's requirements.

There are electrical counterparts of the mechanical analogue computer Instead of a mechanical position, we can have an electrical charge, instead of a velocity, we may have an electrical current, or the magnetic force induced by it. Circuits with resistance, inductance and capacitance are set up to behave in accordance with stipulated equations An electrical transformer can multiply in the same manner as a pair of gears. Vacuum tube circuits can integrate. Such machines are being produced in considerable numbers—the Reac made by the Reeves Instrument Company is a successful example, automatically tracing out the answer to a calculus problem in a series of curves. M. I. T. has an electrical successor to the mechanical analyzer which looks like a telephone central station.

The analogue computers are likely to be less bulky and expensive than the digital type, they provide quick solutions. But like the slide rule (which is also of the analogue class, because it translates logarithms into physical distances) they have a limit to their possible accuracy. For the higher refinements of calculation, the digital or logical computer is now coming to the fore.

The Digital Idea

The digital computer is distinguished by the fact that it does not measure; it counts. It never responds to a greater or lesser degree; at every stage of its

action. It is an "all or nothing" device, operating with discrete signals that either exist or do not exist

The simplest digital computer is the human hand, from which, of course, we have our decimal system. Corresponding to such primitive indicators of a numerical unit as a finger, a pebble or a stylus scratch, the new automatic computers represent digits by such methods as.

A round hole in a strip of tape.

A square hole in a piece of cardboard

A current in an electromagnet.

An armature attracted to the magnet.

A closed pair of electrical contacts.

A pulse of current in an electrical transmission line.

An electronic tube in which current is permitted to flow from filament to plate.

A magnetized area on a steel or alloyed wire.

A magnetized area on a coated tape

A darkened area on a strip of photographic film.

A charged area on the face of a cathode-ray tube.

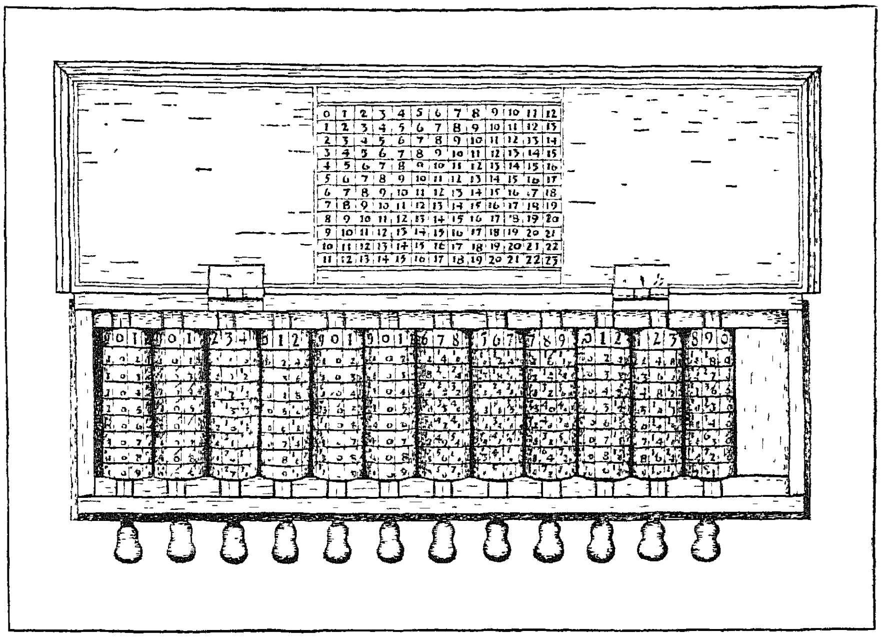
A moving ripple in a tank of mercury.

In each case there is no measurement of gradations in the signal. There is either a hole or no hole, contact or no contact, current or no current, pulse or no pulse. The designers simply have to make sure that there will be no ambiguity. They have to leave enough room on a tape, for example, so that a magnetized area will not get confused with an unmagnetized one. This sort of consideration, however, only limits the compactness and in some respects the speed of the machine; it does not affect the accuracy or the number of decimal places to which a calculation can be carried out.

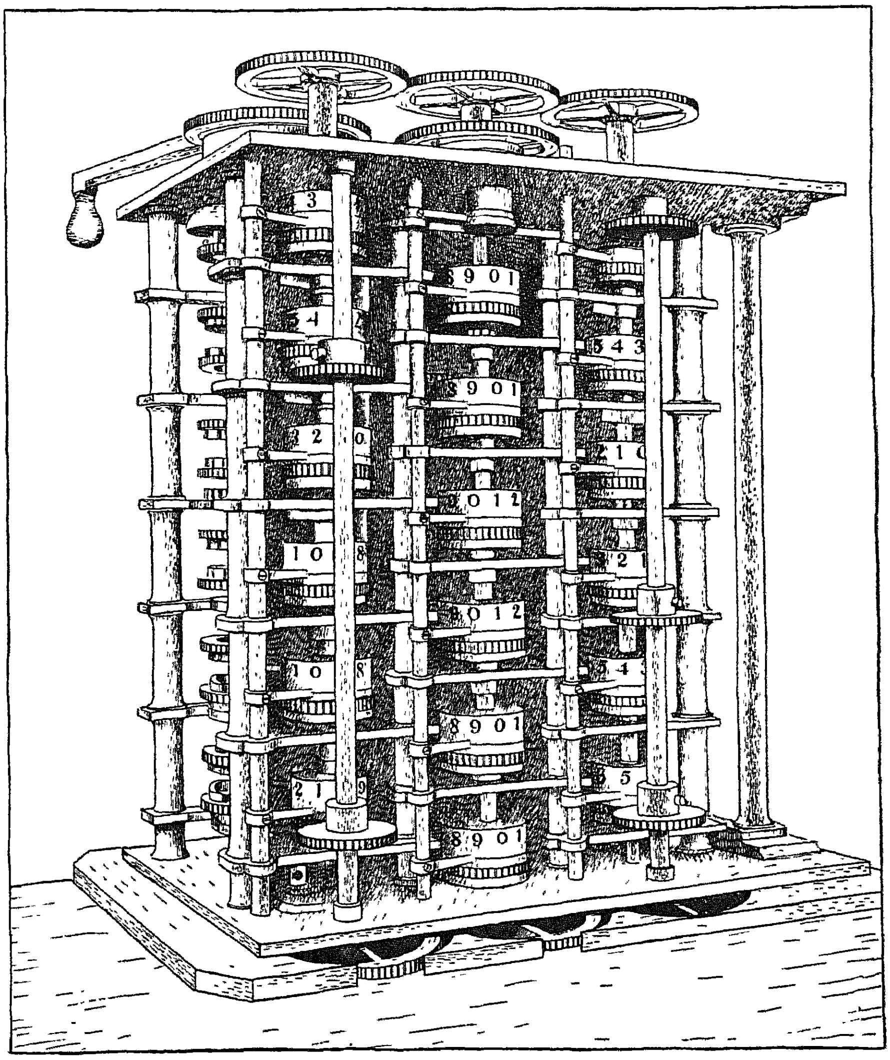
Any such imprint or setting is called a "memory." The use of "memory" as a technical term of the computer trade has bolstered their anthropomorphic analogy to "brains." But there really is nothing surprising in it. Every photograph, every printed page, every canceled check, is a form of mechanical memory.

The important thing about the computer devices is not that they can record and remember numbers, but the fact that they are peculiarly adapted to yield up the memory content quickly, and in a form suited for immediate transportation and processing in other parts of the same machine. The "on-off" or "yes-no" kind of contrast makes it easy to transfer a record from one form to another: a pattern of punched holes instantly becomes a pattern of closed switches, or a pattern of conducting electronic tubes; it is the pattern that represents the number.

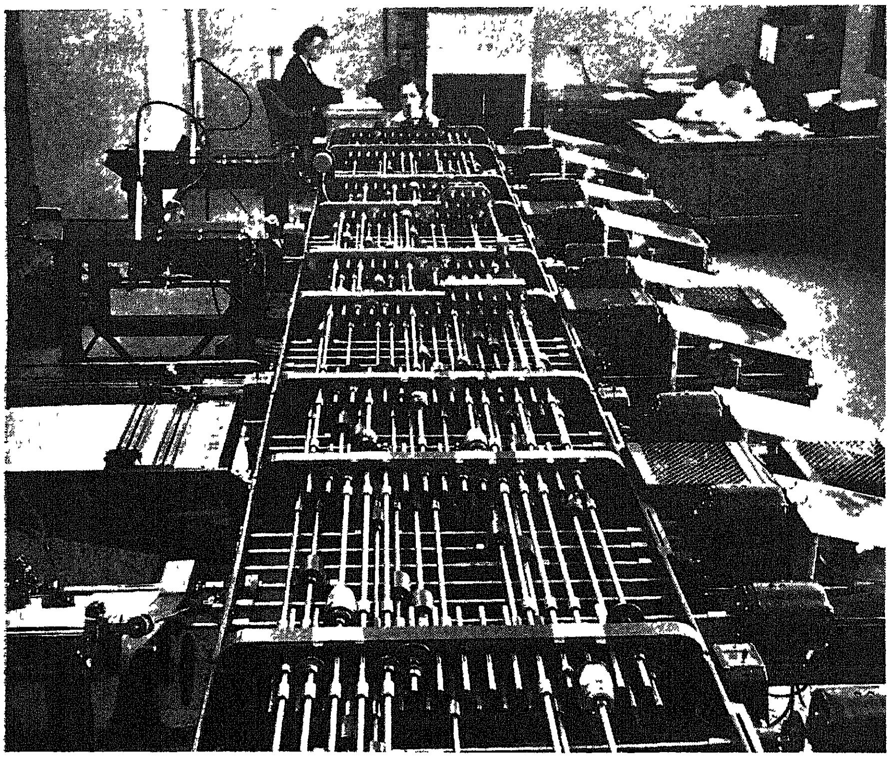
Of course, the number 1,000,000 is not represented by a million spots, holes, or ripples. Even when transmitted at the rate of a microsecond per unit, that would mean a million steps and take the uncon-



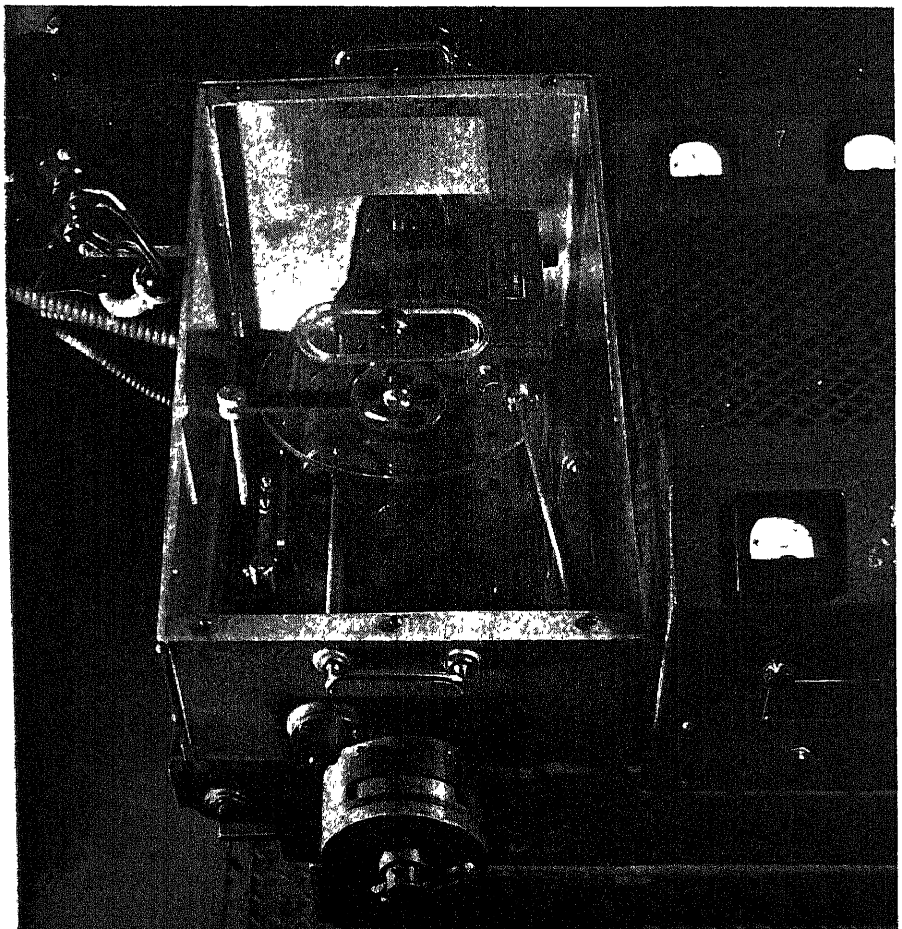
NAPIER'S RODS were a 17th-century attempt to mechanize multiplication. They were never made to work satisfactorily. The inventor, John Napier of Edinburgh, is better remembered because he was the inventor of logarithms.



DIFFERENCE ENGINE, conceived in 1820 by the English mathematician Charles Babbage, was the first modern mathematical machine. It did not work because artisans of his time could not make sufficiently accurate parts.



DIFFERENTIAL ANALYZER in the Ballistic Research Laboratories of Aberdeen Proving Ground was built in the 1930s by the Massachusetts Institute of Technology and the Moore School of the University of Pennsylvania.



KEY ELEMENT of the differential analyzer is the integrator. The essential parts of this device are a disk and a small wheel which turns on its surface. These turning parts are regulated to integrate two separate rates of change.

sonable time of a full second. The answer, obviously, is the same one we use in ordinary calculation—position value coding, of which the decimal system is the most familiar example.

Digits Mechanized

The first artificial digital computing device was the abacus, a manually operated mechanical memory of great antiquity, yet far in advance of mere finger counting. It is still efficiently used in many parts of the world, including the Chinese laundries of the U. S. The next advance was the adding wheel. Gottfried Wilhelm Leibnitz, who invented the calculus independently of Isaac Newton, also invented the stepped wheel that became the basis for the first commercial calculator. Adding wheels of one sort or another led to the modern desk calculator. Without the various office machines that add, subtract, and multiply at the touch of fingers on a keyboard, it would be difficult to imagine an economy that includes vast insurance companies, closely audited chain stores, and banks competing for personal accounts at 10 cents a check. Were it not for the mechanization of business mathematics, modern industry would need more bookkeepers than factory hands. The scientists, ranging from social statisticians to nuclear physicists, have made full use of these commercial devices. The adding machine is as much a tool of the laboratory as the test tube and the oscilloscope.

A further development, suitable to an electrified era, began in the U. S. with the census expert Herman Hollerith. He developed the first punched-card machine using the position of holes to remember numerical data. In the 1890 census it proved its worth by reducing the labor in half. The Tabulating Machine Company which he organized in 1896 was later consolidated into the International Business Machines Corporation.

The IBM card, standardized in a size of three and a quarter by seven and three-eighths inches, with its 80 columns of 12 punching positions each, has become a kind of mathematical coinage. It is interchangeable among a variety of punching, sorting, tabulating, calculating, and accounting machines, which deal with the cards mechanically, electrically, and electronically. The same kind of card may hold the data of an astronomical orbit, an accountant's audit, a corporation's income tax, or a subscription to this magazine.

The IBM cards, or variations thereof, not only paved the way to the modern electronic brains, but in many cases they constitute a vital part of them. The cards with punched holes speak just the kind of language that an electrical machine understands. From them the ma-

chine reads its assignment, upon them it spells out its answers, and with stacks of them it forms its library or memory.

Quite comparable in importance to the development of modern computers, although somewhat overlooked, is the telegraphic printer or teletype. This is the machine that can be seen typing, no hands, in every newspaper office, every news agency bureau, every telegraph office, it is the machine that reads and writes at a distance. The essential elements in this mechanized communication are the relay and the perforated tape. The relay is the lineal descendant of the telegraph relay, switching on new electrical circuits as an armature responds to the electromagnetic pull induced by an incoming signal. The perforated tape has room for five meaningful holes, plus a sixth little sprocket hole which serves to advance it through the reading apparatus.

Note well the mathematical meaning of five holes, or lack of holes, across the width of a paper tape. How many different meanings can be conveyed by this "five-unit code?" The answer is 32, and the way we arrive at it illustrates the binary system of numeration that appears in the most advanced electronic brains.

The first position on the tape may be either perforated or blank, that accounts for two possibilities. Each of these can be associated with a second position that either has a hole or has not, that makes four possibilities. The third, fourth, and fifth positions each in turn doubles the number of alternatives, giving a total of 2^5 or 32. Of these, 26 are used for ordinary purposes of communication to represent the letters of the alphabet, and five for other commands to the mechanical typist: space (between words), carriage return, line feed, shift to letters, shift to figures. (One of the 32 positions is usually not utilized for any signal.) The ability to put such commands in code and to have them carried out by relays is another major ingredient of the electronic brain.

The width of such a tape, with its 2^5 choices, represents a five-digit number in the binary system. Some tapes employ a six-unit code, providing 64 choices.

The Relay Computers

It is possible to build a fairly fast computer using nothing much besides teleprinters and tape punchers, a switchboard and wiring, and a collection of adroitly interconnected relays. It is not only possible—it has been done by the Bell Telephone Laboratories.

The perforator presents the problem in the form of punched tape. The relays (standard items of any telephone dial center) do the calculating. The trick of adding is to wire their contacts and coils in such a way that the closing of any two relays energizes the relay that represents the sum. For instance, if relay No. 1 and relay No. 3 are simultaneously closed, the only possible path presented to an incoming current is the one leading through its closed contacts to the coil of relay No. 4. However, if the incoming current arrives from the "carry in 1" wire (meaning that there was a "1 to carry" from the previous column of the addition), the path leads to relay No. 5.

The Bell Telephone Laboratories are not in the computer business except as it serves the telephone business. But the engineers had to do a lot of calculating in that business, and George R. Stibitz, then of Bell Labs (now an independent consultant to the computer industry), conceived the idea of building a robot computer out of the familiar machinery of the telephone system, and the first of a series of five progressively more complicated computers was built by Bell in 1939.

Characteristically, the communication engineers were not satisfied merely with a relay robot that could calculate. What good was all that saving of mental labor if they had to walk around the labyrinthine corridors of the laboratories to get to the machine? So they also substituted wiring for walking, and rigged up three remote stations, on various floors, at which mathematical problems were teletyped in (unless, of course, they got a busy signal), and at which the answers were typed back. This feature seemed fairly commonplace to the telephone men, and they were somewhat surprised at the amazement of members of the American Mathematical Society when, in a 1940 meeting at Dartmouth College, problems put on a long-distance circuit from Hanover to New York received an immediate answer on the teletype printer. Actually it was no more difficult than sending the answers across the room.

Compared with the electronic devices we shall discuss below, the relay computers are slow. On the other hand, they are reliable. One machine ran 1,500 hours without a failure. They check themselves, refusing to let an error go through even when they are unattended. When some element in the apparatus fails, the machine simply drops that portion of the problem and proceeds to the next.

During the war IBM built several relay computers, two of which have been installed at Columbia University, and, under the supervision of W. J. Eckert, are available to scientists engaged in basic research. The first of the large-scale calculators was the Mark I, or the Automatic Sequence Controlled Calculator, which IBM presented to Harvard University, where it went to work in April, 1944. Using adding wheels controlled by electrical impulses, with relays for traffic direction, it calculates with numbers of 23 decimal digits and computer products to 46-digit accuracy. It gets its instructions from perforated tape, from IBM cards, and from the manual setting of 1,440 dial switches. It emits its answers either on IBM cards or by typing columns of figures on a roll of paper.

Electronic Computers

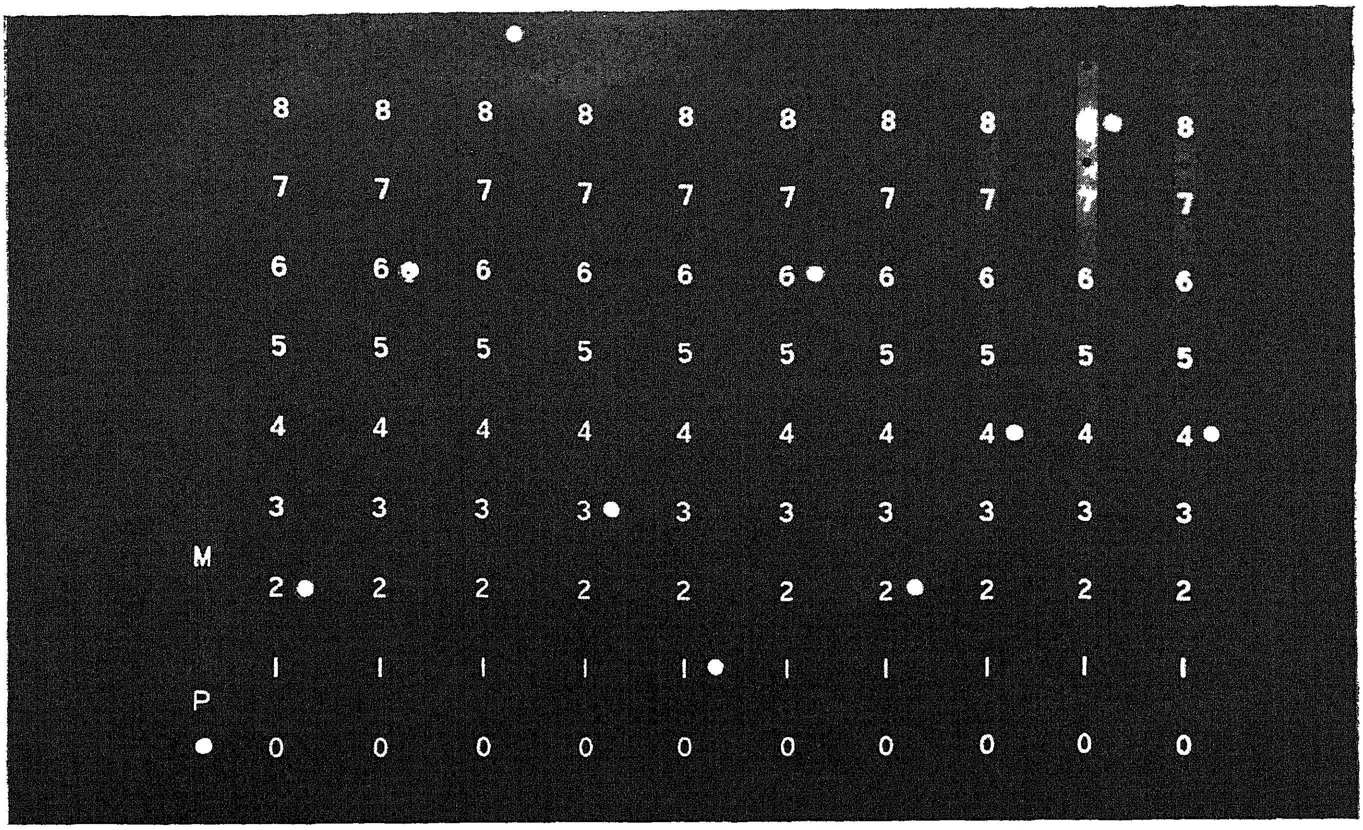
What do relays really do? They are nothing but switches operated by electricity, so that one signal opens a valve or gate through which another current can pass. The very same thing can be done by an electronic tube—it is for this reason that the British use the word "valve" where we use "tube." The electronic valve does what the relay does—and does it thousands of times faster. In the relay, a mechanical object must move through space to open and close the gate. In the electronic tube, only electrons move, and their speed can best be indicated by the fact that in a radar set, electronic currents reverse themselves millions and even billions of times per second.

The first mathematical computer to employ the electronic swiftness of radio and radar was built in wartime secrecy for the Army Ordnance Department at the University of Pennsylvania, and later moved, at a cost of about $100,000, to the Ballistic Research Laboratories at the Aberdeen Proving Ground. It is the Electronic Numerical Integrator and Computer, the previously mentioned Eniac. This phenomenal machine is so complicated that no single person, even among its inventors, knows every part of its wiring or the function of each of its 18,000-odd tubes. However, some of its arrangements are quite simple. The system of electronic number storage, or memory, is obvious almost at first glance.

If you were admitted by Army Ordnance officers to the new air-conditioned quarters of the Eniac, you would observe the walls lined with panels of radio tubes. You are shown one panel called an accumulator, and you are told that it is capable of remembering a 10-digit number. It can register any number from zero to 9,999,999,999—but only one such number at a time.

An accumulator consists essentially of 100 vacuum tubes (one might say 200 tubes, since each is a double triode). They are arranged in 10 columns of 10 tubes each. Reading from right to left, you have the units column, the tens column, the hundreds column, and so on. In each column, the bottom tube represents zero, the second tube represents 1, the third tube 2, and so on to 9.

To make things even easier, there is a neon light in front of each tube which goes on when that tube is in the "indicat-



ACCUMULATOR of the Eniac computer operates on the decimal system. It has a "memory" of 10 digits (*horizontal rows*). Letters M and P at left stand for minus and plus. Number indicated by neon lights is 2,693,162,484.

ing" state. Only one tube in each column can be indicating. If the number is 5,384,293,768, tube 5 will be excited in the first column, tube 3 in the second column, and so on. If the number stays put for a few seconds (which in practice it does not, except during demonstrations or checkups) it is quite easy even for the untutored to read the number written on the wall.

The Eniac has 20 such accumulators, which occupy about half of the machine's total space. Thus it can store just 20 numbers (of 10 digits each) in its "electronic memory." At least one of the accumulators will be in use at any given moment in a dynamic way—either sending out the number which it has been holding or receiving a new number. The new number may come into a blank accumulator, on which it registers, or it may come into an accumulator which already holds a number. In the latter case, the new one is automatically added.

And here, at a flash, we see the machine's wonderful possibilities. An accumulator can absorb a 10-digit number (adding it, if necessary, to its existing contents) in just one five-thousandth of a second. Or, to use the kind of time unit which is more suitable to this discussion—in 200 microseconds.

One peculiarity of the high-speed calculators is that it takes no more time to do the most elaborate addition than the simplest. The Eniac needs as long to add 1 and 1 as to add two full 10-digit numbers. In fact, an accumulator gets its maximum workout when it is required to subtract 1 from 1. Since it works in one direction only, it cannot simply go back one step from 1 to zero. Instead, the minus 1 is set in as 9,999,999,999, *i.e.*, 10 billion minus 1. It then adds 1 to 9,999,999,999.

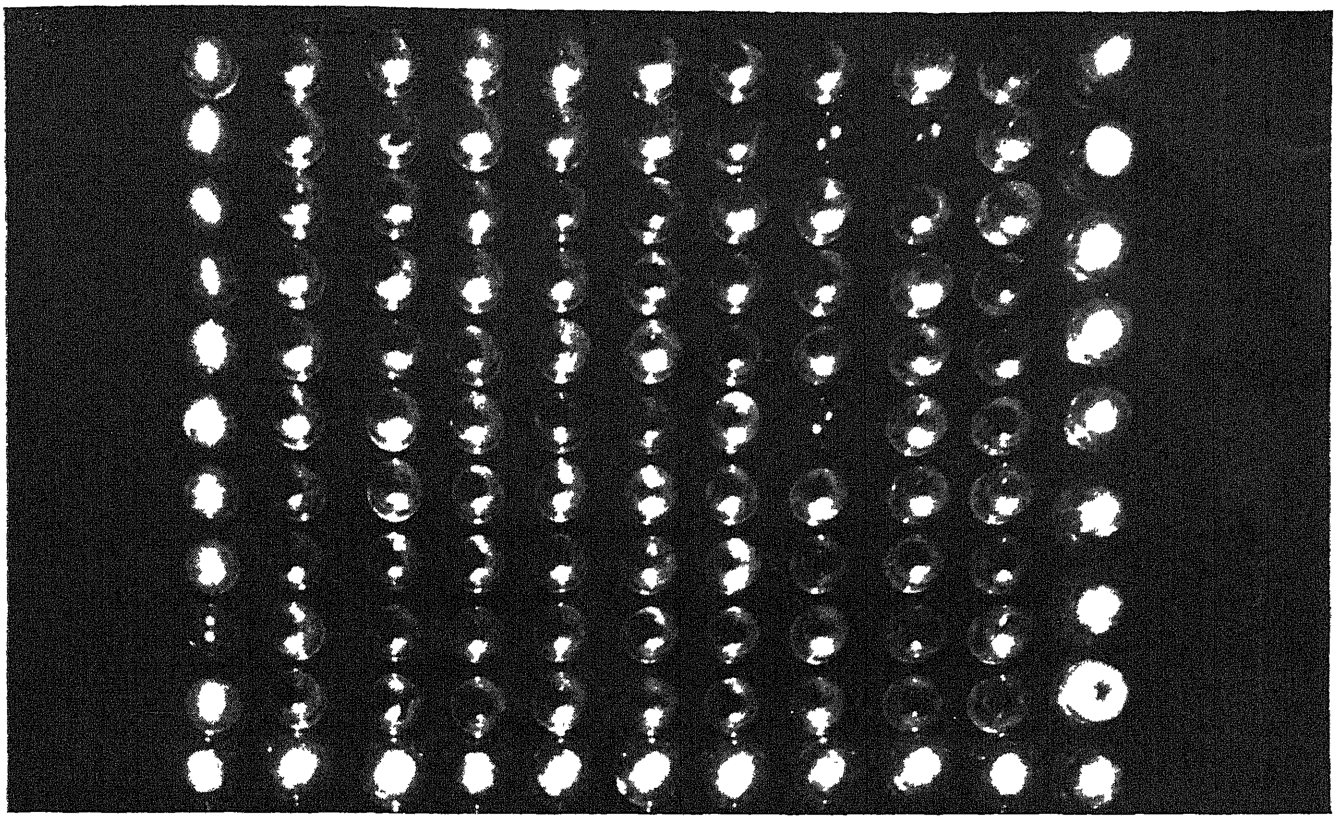
In performing this addition, the machine functions as follows. A single pulse of electricity representing the number 1 goes into the units column. At the first tube position it finds that a free path exists for it to go to the second tube. There, also, the gate is open, and so on through successive tubes to the top of the column. The impulse travels to the tube that represents number 9. The "flip-flop" circuit at 9 position has been in the "on" condition. At this point three things happen: First, the impulse turns the top tube to "off," clearing away the 9. Second, it continues to the next tube position, representing zero, and switches that to the indicating condition. The units column now reads zero, as it should. But if you were doing this mentally you would say "zero and one to carry." To correspond to this, as the third step the activation of zero causes a single pulse to be carried to the tens column. Here the pulse runs through precisely the same routine, finding its way up the column to change the excitation from 9 to zero, and sending a carry into the hundreds column. This is repeated until the entire array has been changed from 9,999,999,999 to 0,000,000,000. The machine, doing it the hard way, has carried out the calculation 1 minus 1 equals zero.

Suppose the number to be added is 1,000,000,011. Then single pulses will enter at the same time into the units column, the tens column, and the billions column. After each one runs through its cycle, another timed signal comes along which instructs each column to yield its "carry" signal, if it has one in store, to the column on its left.

What about multiplying and dividing? These could be done, and in some calculators are done, by repeated addition and subtraction. Multiplying 52 by 7 simply means setting up the number 52 and adding 52 six times. Similarly, division is repeated subtraction. There are, however, some short cuts. Eniac uses a built-in multiplication table. This is wired up to give immediately the product of any two digits. The sums of all the products are then fed into an accumulator and added up. By this method the entire multiplicand can be multiplied by one digit in the time corresponding to one addition. The complete multiplication of a pair of 10-digit numbers can be accomplished in 1/350 of a second.

Any numerical computation, whether it deals with an equation or a table of numbers, can be reduced to a succession of the basic arithmetical operations.

Eniac was designed for a specific purpose. The Ordnance Department needed firing tables—a different one for every new kind of gun, and for every different size and shape of shell. The Army had



ELECTRONIC TUBES are the counting units of the Eniac accumulator. Each light of the panel on the opposite page represents a tube. There are 10 columns of 10 tubes. Bright tubes at right and bottom are auxiliaries.

large numbers of skilled mental laborers, sitting at desks with their fingers punching the keys of office-type adding and computing machines, figuring out the necessary tables. It took such a person 20 hours to work out the trajectory of a single shell, making allowance for air resistance and the many other factors. Eniac does the same thing in half a minute. The implications of such speeds for the remote control of guided missiles are evident.

Although Eniac was a tremendous success in its way, opening the path to all-electronic computation, nothing exactly like it will ever be built again. It has serious limitations. Chief among them is a vast discrepancy between the speed with which it can compute and the time it takes for it to become aware of the problem and to spell out its answers.

For a given kind of problem, it must be instructed by plugging in wires and setting switches—both of them manual operations that go at the poor speed of human hands. In addition it has so many components that there are numerous sources of malfunction requiring elaborate maintenance routines. Another limitation, which became evident to its designers even while it was being built, is the limited electronic memory and the large space required for storing numbers in electronic tubes. The tubes require 120 kilowatts of power, and another 20 kilowatts is needed for the blower equipment to take away the heat in the tubes. This led to the conclusion that the use of 100 tubes to spell out a 10-digit number is wasteful of space and power

There is a way to make a memory composed of electronic tubes more compact. The IBM Selective Sequence Electronic Calculator in New York is an example. The machine deals with 14-digit numbers On the Eniac principle each number would require 1,400 double tubes. This machine gets by with 560. (In both the Eniac and the IBM machine there are various auxiliary tubes to control the circuits, but these are ignored here.) This is done by modifying the decimal system, using a hybrid called "binary decimal"

Any number from zero to 9 can be represented by only four tubes, provided each tube has a numerical value associated with its position in the group, and provided that more than one of the group can be "on" at the same time. The values chosen are 1, 2, 4 and 8. Thus:

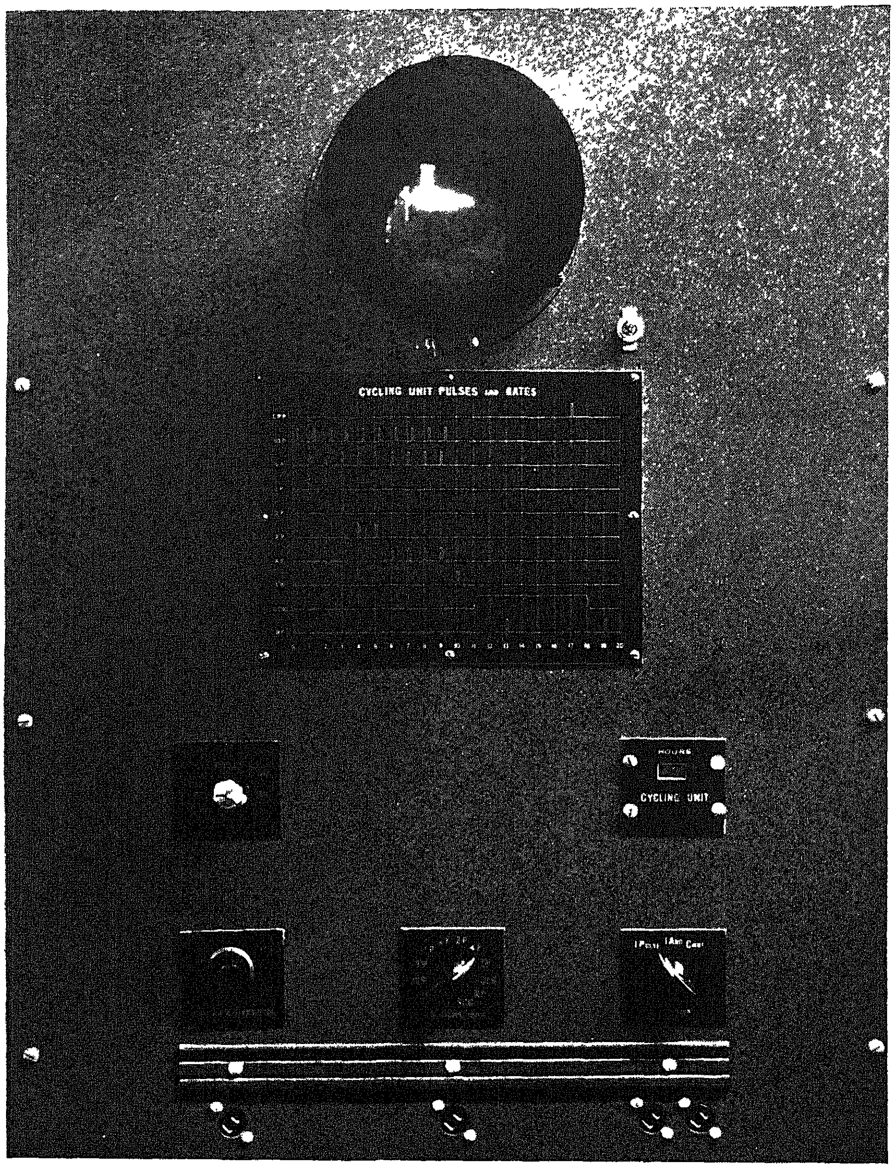
1 is represented by tube 1.
2 is represented by tube 2.
3 is represented by tubes 1 and 2.
4 is represented by tube 4.
5 is represented by tubes 4 and 1.
6 is represented by tubes 4 and 2.
7 is represented by tubes 4, 2 and 1.
8 is represented by tube 8
9 is represented by tubes 8 and 1.
0 is represented by all tubes off.

This system of binary-decimal digits is applied not only to electronic tubes but also to banks of relays and rolls of paper tape, which provide a vast storage of numbers and sequence instructions. At the input and output connections to the external world, the machine has an automatic device for translating between the decimal system and the binary-decimal.

In many cases there are good reasons for sticking to the decimal system, at least as far as the machine's external relations are concerned. One very practical reason is that the IBM calculators and the Eniac were built to receive their problems from the punched holes of standard IBM cards. IBM's newest calculator, the Type 604 mentioned earlier, employs the binary decimal system, four tubes per digit, in connection with standard punched cards that are completely read and processed at the rate of 100 per minute.

The decimal system is also desirable wherever the machine must handle large amounts of "outside" numerical material. Thus it will probably continue to be used in any "business" type machine which handles accounting problems, inventories, tax computations, or in any "scientific" machine which deals with statistical material. One of the most advanced calculator designs—the Univac, being built by the Eckert-Mauchly Computer Corporation for the use of the Census Bureau—also will operate on the decimal system.

On the other hand, when the Eckert-Mauchly group got orders for a computer to do engineering problems where the prime purpose was to solve equa-



CODED PULSES are fed into the Eniac machine by cycling unit. Characteristics of pulses may be observed on the face of the cathode-ray tube at the top. A four-peak signal is shown on the tube. Key to code is in the center.

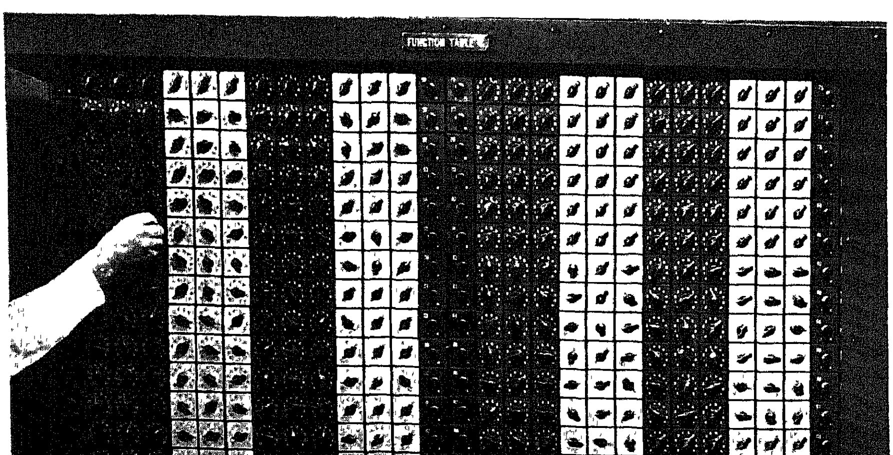


TABLE OF FUNCTIONS is used as an Eniac auxuiliary. Numerical values representing quantities that change in relation to each other may be set up on table. These are fed into machine at appropriate points in a problem.

tions, it was designed for the binary system (hence the name Binac—binary automatic computer). The calculator being built at the Institute for Advanced Study, in Princeton, for theoretical analysis of problems in mathematical physics, weather forecasting, and other problems of that nature, also will work on a pure binary system.

Binary Numbers

The binary system permits the "on-off" kind of memory to be used with 100 per cent efficiency. As long as we have no special reason for compromising with the decimal notation, we can have our tubes signify 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1,024, doubling at each stage, as far as we like. Any intermediate number can always be assembled by appropriate combinations of the tubes.

At this point we find that we no longer need the decimal notation at all. There is another notation which serves the purpose better. The binary system of numbers really requires only two symbols, which are usually written as 0 and 1. Let us first compare it with the above list of doubling numbers.

Decimal notation	Binary notation
0	0
1	1
2	10
4	100
8	1,000
16	10,000
32	100,000
64	1,000,000
128	10,000,000
256	100,000,000

One inference is obvious at a glance. To multiply a number by 2, just add a zero. Or, in a machine, shift the columns one step to the left. Thus multiplying becomes as easy as adding.

Now let us see how the other numbers fit in. We will take just the first few

Decimal	Binary
3	11
5	101
6	110
7	111
9	1,001

Thus it is clear that every number can be represented by some combination of the two symbols 1 and 0. The presence of one or the other constitutes a binary digit. The phrase binary digit has been abbreviated in a new term—"bit," a rather neat usage because it is essentially a bit of information. In the binary system we need 10 bits to represent a decimal thousand, 20 bits to represent a million, 30 bits to represent a billion, and approximately 33 bits to represent the ten-billion figure of an Eniac accu-

mulator. It takes only one electronic tube to represent a bit Thus 33 tubes do the work that in the Eniac requires 100 and in the binary-decimal system would require 40.

In addition, binary notation thrives on the simple contrast of two alternatives—the ultimate in interchangeability and transportability The 1 and 0 we have used in the above explanation can be translated physically, and without any further coding, into all sorts of interchangeable effects—spatial, electrical, magnetic. For example, 1 may be represented by an electric pulse and 0 by the absence of a pulse, 1 by magnetic north and 0 by magnetic south, and so on.

Any such representation may be used as long as it is consistent and interchangeable As a magnetized tape passes under a coil, the presence or absence of a magnetized spot is converted into the presence or absence of an electrical signal, which in turn can be routed to an electronic tube. If there is a signal (meaning 1) the tube can be flipped from a 0 position to a 1, or from a 1 to a 0. The beauty of the binary system is that addition of a digit always means a simple reversal of the condition of the "memory"—adding a pulse where there is none, or wiping it out if there is one (converting 1 to 0).

Logic and Control

The next step is the realization that the binary system does not merely apply to numbers. It applies to logic. For 1 and 0, we can substitute "yes" and "no" Thus, for example, a binary machine may be adjusted to deal with double negatives, making "no" and "no" add up to "yes." The vacuum tube lends itself especially well to acting out such logical concepts as "and," "or" and "neither." To illustrate the idea of "and," a four-element tube has two grids that act as "gates" controlling the current from grid to plate. If both of them are normally held at a strong negative voltage, current can flow only if both are turned positive by an incoming signal. Signals on each are a "necessary" condition for any current to come out of the tube; neither alone provides a "sufficient" condition. On the other hand, external circuits can be so arranged that a signal from either one of two sources will make the tube conduct; such an arrangement carries out the idea of "or," since one source or the other will suffice

Such electronic gates are at the heart of the traffic and control systems of the high-speed calculators. Each gate may have one, two, or more locks, requiring certain simultaneous conditions to be satisfied before they will permit the machine to proceed to the next step.

The speed of the electronic tube is the key to the speed of the new calculators. We have already seen that the tubes are used in three ways. first, as a memory device which can receive and hold numbers; second, as an arithmetical unit; and third, as a gate for directing the flow of electrical traffic to different parts of the machine in accordance with instruction signals. Vacuum tubes have a fourth important function in making the calculators possible, they are employed, somewhat as in radio and television sets, to amplify worn-out signals that have lost their sharpness and strength, reshaping them as good as new

Of the four functions, the least efficient is the one described at the beginning of this article—storage. And that is because it takes the length of a wall to store any appreciable quantity of numbers, whether the tubes are used 10 to a decimal digit, or four per decimal digit, or even one per binary digit. For really large-scale computations, machines need a memory that is both more compact and more capacious than any that can be achieved with electronic tubes.

One recourse is to have the machine print out partial answers which can then be fed back into it—or other machines—when needed. The IBM Selective Sequence Calculator makes considerable use of this method. As the machine solves some mathematical function, the resulting table of values is perforated in a coded set of punched holes on a wide roll of heavy paper, not unlike an old-fashioned player-piano roll. This is mounted on an arrangement of cylinders and pulleys. Later, when the machine is ready to refer to the table, it "looks up" the proper constant by letting the paper run through it until it finds the appropriate value. On a similar principle, the machines can have a virtually infinite memory capacity in the form of punched cards, but the speed of this method is limited by the slow rate at which the machine reads the cards—100 cards per minute.

To get to another order of magnitude for compactness and speed of memory, designers have turned to methods other than perforated paper. Among them are: magnetic tape, photographic film, charged cathode-ray-tube surfaces and, most remarkable of all, columns of mercury in which numbers are stored in the dynamic form of waves moving at the speed of sound.

Magnetic tape, the same kind now coming into favor for recording the sound waves of radio programs and dictating machines, is being used widely in machines now under construction: both the Edvac and the Univac will make important use of it. Its advantage is compactness: a one-inch strip of eight-millimeter tape can hold 800 distinguishable "spots" of magnetization—carrying as much information as an entire IBM card. Besides, as users of tape-recording equipment know, the magnetization can be applied at high speed, can be read back just as fast, and can be erased more easily than a blackboard.

Another experimental approach is through electrostatic storage. The principle starts with the cathode-ray tube that forms the viewing screen of both radar and television sets. The memory that such tubes have for a picture can also be used to store patterns of electrical charge. The idea is attractive because the "reading" of stored numbers can be done very quickly by means of a beam of electrons. RCA engineers have built a tube for the purpose called the Selectron, with a mesh of wires built in to control the area on which electric charge is deposited, and this is one of the elements under test for the computer being built at the Institute for Advanced Study. A new British calculator at Manchester University uses a regular television tube, with dots on its face for zero and dashes for 1. The U. S. Bureau of Standards has plans for employing the same device.

But what really seems to symbolize the speed of the modern computer is the new tendency to resort to memory-in-motion through the use of the mercury column.

Pulses in Mercury

Mercury memory came out of wartime radar. One tactical difficulty with radar was the fact that an enemy plane could not well be distinguished against a solid background. It could conceal itself from the radar eye by hiding in front of a mountain as well as behind it. Engineers reasoned they could get around this difficulty if they could find some automatic way of canceling out a fixed echo and showing only those received from a moving object. This was finally accomplished, toward the end of the war, with a device called the delay line The idea was to make an echo signal travel tardily within the set so that the following echo, arriving perhaps a thousandth of a second later, would overtake it. If the two matched, they would cancel each other out. Thus echoes from fixed terrain would not show. But if the echoes came from different places, as they would from a moving airplane, both of them would appear on the face of the oscilloscope.

One of the best means of delaying such a signal was found to be an "acoustic" line in which the signal would generate a ripple in a tube of liquid mercury. Traveling in the mercury at the speed of sound, the signal would come out at the far end an appreciable interval after its entrance. The exact period of delay could be adjusted by changing the temperature of the mercury or the length of the path through it. For example, at 65 degrees Centigrade ripples travel through mercury at a mile a second. In electronic matters, where most events occur closer

to the 186,000-mile-per-second speed of light, this is slow

In the Binac now being completed by Eckert-Mauchly, an 18-inch column of mercury maintained at 65 degrees provides a delay of 336 microseconds. Since successive pulses in this machine are separated by only one quarter of a microsecond, this delay means that at any given moment the 18-inch length of mercury has in storage four times 336, or 1,344 binary digits. For convenience of executive administration, this is divided into 32 "words," each containing 30 binary digits, a pulse space for plus or minus sign, and 11 more unused spaces (or time intervals) to separate successive words.

The mercury tube is the kind of "brain" in which information is supposed to go in one ear and come out of the other. An electrical signal arriving at the delay line causes a quartz crystal to expand by the well-known piezoelectric effect. The crystal pushes against the mercury, and a ripple runs through faster than the eye could follow. After 1/3,000 of a second it arrives at the far end, presses against another crystal, and generates a new electrical impulse. This is built up in an amplifier and fed back into the front end again. The cycle repeats 3,000 times a second. Thus the digit goes around and around, and would do so just about forever if nothing intervened. At the desired moment, however, an electronic gate opens in the amplifier to switch the signal into some other circuit—the electronic adder, for example Or the signal can be erased, simply by instructing the amplifier not to amplify at the moment when the signal comes around.

At the present writing the most popular system for calculating machines is based on the mercury ripples, supplemented by electronic computing circuits, magnetic wire or tape for intermediate and erasable memory, punched cards or paper tape for a still more permanent library of memories and accumulated answers, and automatic printers for spelling out the answers.

Future Applications

What does this all mean in practical terms, for today and tomorrow? How will it affect business, government, military affairs, science, and mathematics itself?

It is tempting to make grand generalizations. The writer is indebted to Samuel N. Alexander, chief of the Bureau of Standards' electronic computer section, for a rather hardheaded appraisal of some real prospects—purposes for which various branches of the government are submitting their bids to be among the first to get such machines.

First, there is the matter of enormous numbers of routine substitutions in formulas An important example, aside from the mission of wringing more results from the figures of the 1950 census, is the adjustment of maps. Many nations may be correctly mapped, but two adjoining countries are likely to have a discrepancy of several feet at their mutual boundaries; the corrections require a tremendous number of separate calculations, and both the Army Map Service and the Coast and Geodetic Survey would like electronic assistance.

Secondly, there are elaborate engineering computations which now require enormous effort—for example, a roomful of people spending more than a year and a half checking stress estimates to transfer a design from a model to a full-size airplane This kind of thing, along with many problems in hydrodynamics, supersonic airplane characteristics, and so on, can henceforth be relegated to the computing machine. The slowness of ordinary computation was partly responsible for the fact that no U S. bomber flew in the last war which had not been designed before the war began. This lag should be greatly reduced by the new computers.

Thirdly, there is a group of uses that have to do with "program procedure." What is the best way to distribute available manpower, funds, equipment, and so forth, to maximize a particular effect or to minimize cost? For example, the armed forces can make up various menus which will satisfy the soldier's needs for calories, vitamins and minerals. But each food item also has various such qualities as perishability, compactness and cost. How can you meet the dietary requirements with minimum cost, minimum shipping weight, or minimum time of delivery? Normally the mathematical labor in figuring out the advantages of every possible combination is too great, so only a few combinations are studied thoroughly.

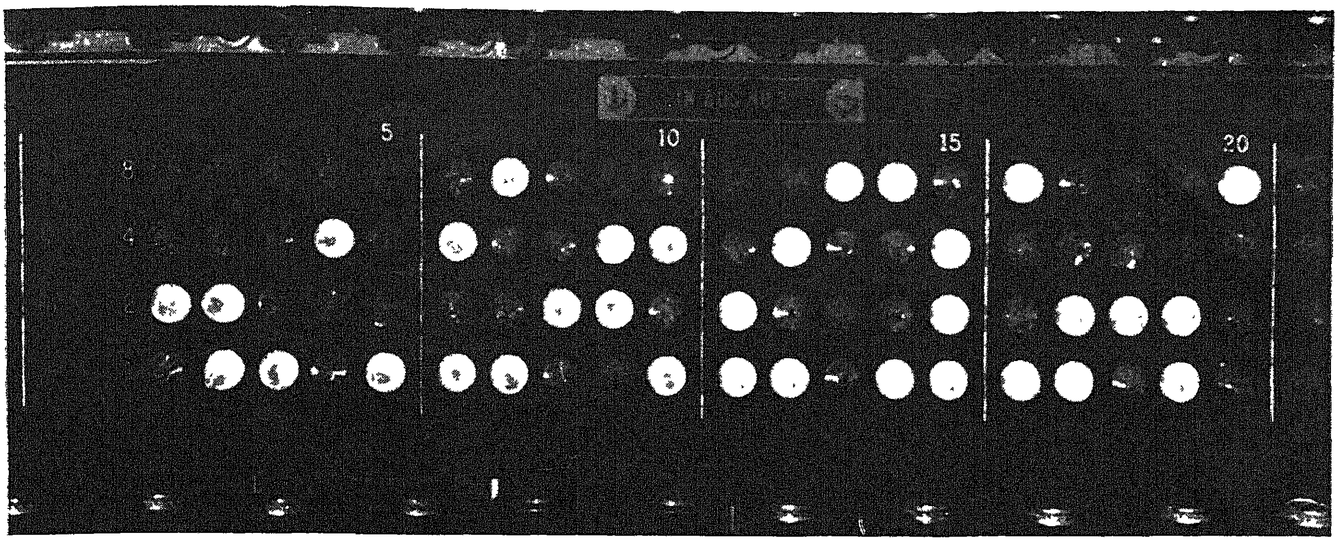
Fourthly, since the digital calculator is essentially a logical machine, it can make all sorts of quick decisions that now require an alert and hard-pressed human being. The Air Navigation Development Board is considering the use of computing machines at airport control towers to relieve the traffic control men of many elementary, stereotyped decisions. And the Research and Development Board of the National Military Establishment has a committee at work considering how electrical computers can be rigged to play out war games.

In the present state of world affairs military applications are still uppermost in the thinking about calculators. The last war undoubtedly stimulated the development of these machines, and the threat of renewed war is a continued stimulant. It seems that electronic computers, associated with radar, will be the main defense against high-speed bombers, tracking the bomber and guiding the anti-aircraft missile to a collision course. And future long-range offensive missiles will most likely radio back what position information they can gather, and have it processed in a home computer, out of which radio-transmitted answers will give the missile its instructions for further navigation.

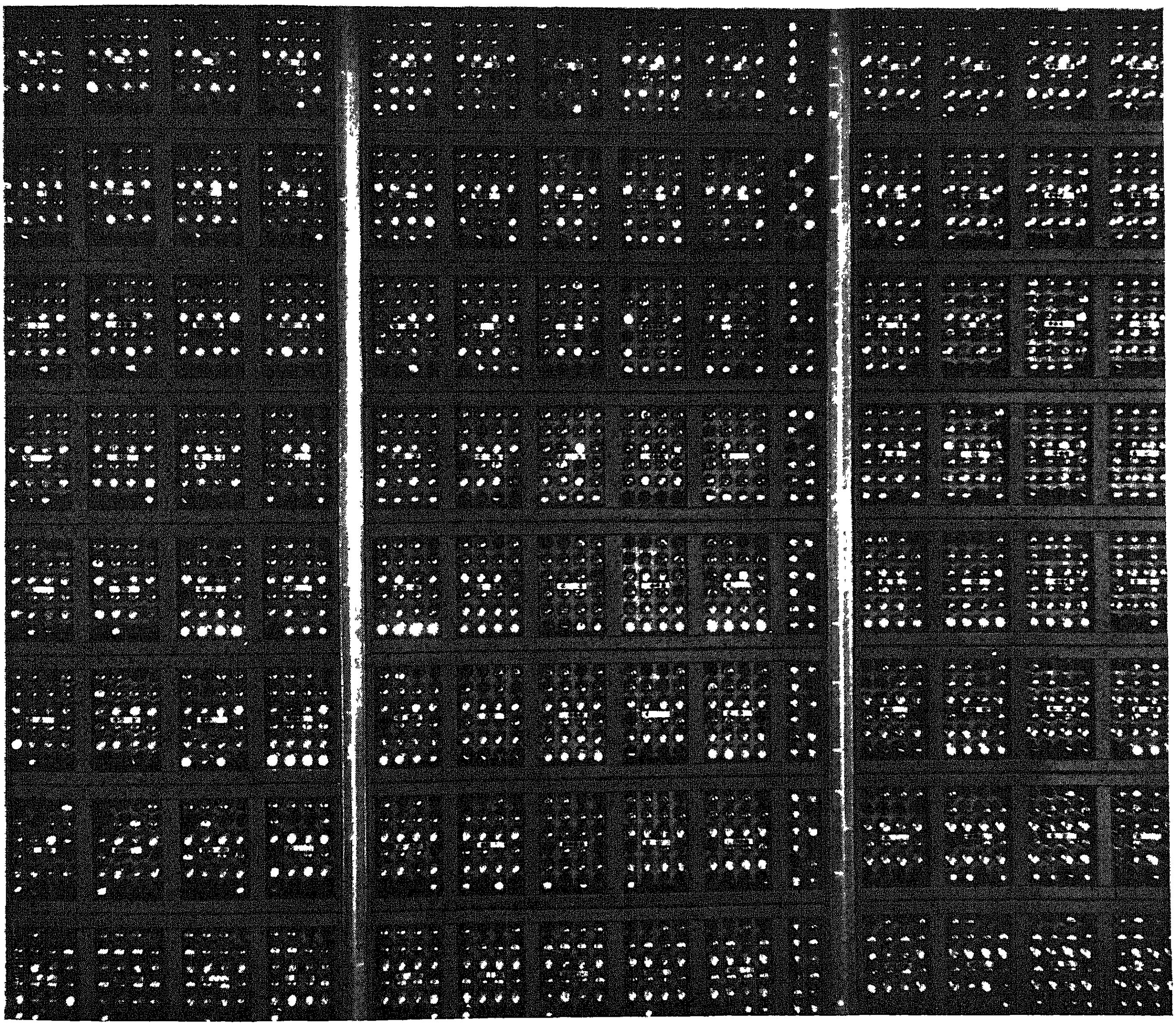
Should the war clouds dissipate, the cleared air would show the electronic brains contributing mightily to the advance of science and the efficiency of both business and government. They may even offer a technical means of contributing to world peace by helping to make world government practical. The "curse of bigness," which has affected big corporations and big governments alike, is very largely due to the difficulty of any small group of men knowing what is going on in a vast and far-flung enterprise. The trouble with planning is that the planners cannot know all the facts bearing on their plans, much less have they the time and ability to figure out all the consequences that will result from one or another course of action. These considerations have brought about a feeling for an optimum size for any single administration, whether government or business, beyond which the operation gets too unwieldy to compete with smaller, better integrated units. The electronic computers or information processing systems may well move that optimum size upward.

Though they replace other kinds of human mental effort, the mathematical machines will never replace the mathematician. More mathematicians will be needed, but the nature of their work will be changed. As theoretical physicists make ever more general equations expressing the basic forces of the universe with fewer and fewer symbols, their abstractions get ever farther from the numerical values of the laboratory experiment and ordinary life. Even Albert Einstein is not free of this difficulty. His approach toward a unified field theory, a generalization into which relativity fits as a part, may or may not be correct. Einstein does not know. The trouble, he once told the writer, is that "tremendous labors of the most brilliant minds, possibly for several generations, will be needed to translate the general theory into specific cases which can be tested by experiment." Perhaps the new computers, like the one being built by Einstein's colleagues at the Institute for Advanced Study, will help to shorten this labor, and thus allow investigators of the mysteries of the universe to test their own theories to determine whether they are on the right track.

Harry M. Davis was author of Radio Waves and Matter, *which appeared in the September issue of this magazine.*



INDICATOR LIGHTS of IBM Selective Sequence Calculator depict binary decimal counting system. Four lights in each column represent 1, 2, 4 and 8. These may be added to indicate any number from zero to 9 Column at left notes plus or minus. Each of 19 other columns is one digit. Number is +3.141592653589793238, or *pi*.



ELECTRONIC-MEMORY SECTION of the Selective Sequence machine is an array of tubes. Each of the panels that contains 24 tubes represents one digit. Four of the 24 tubes indicate the digit by system outlined above. Remainder control route of signals through calculator. Twelve-tube panels are auxiliary control units.

SUBMARINE CANYONS

Cut into the drowned shelves of the continents are some of the world's deepest gorges. A California investigator describes his work and its bold geological implication

by Francis P. Shepard

AN EXPLORER who undertook a walking trip on an ocean bottom—if such a maneuver were possible—might well need mountain-climbing equipment. He would find some of the undersea terrain as rugged as any on dry land, in an extended trip he would encounter deep valleys, tall mountains, sheer rock cliffs. Not the least astonishing of his experiences would be the discovery of vast submarine canyons, rivaling in size and steepness the famous Grand Canyon of the Colorado River. Large canyons are known to exist off the shores of every major continent. They are particularly surprising to geologists because there is nothing in traditional geological knowledge or theory that explains clearly how they could have been formed.

The undersea canyons have the same character as those on land: they are deep valleys with high steep slopes and a narrow floor. The erosion process that creates canyons on land is well understood. Once started, a canyon deepens at a rate which to a geologist, used to dealing in changes requiring millions of years, is truly stupendous. In deposits of sand, gravel or volcanic ash on a steep slope, a stream has been known to cut a canyon 100 feet deep within a single generation. Canyons 1,000 feet or more in depth are believed to have been cut into the sides of some mountain ranges since the retreat of glaciers of the last great Ice Age, that is, in the past 10,000 to 25,000 years.

But how can one account for the cutting of steep-walled canyons in a sea floor a mile or more under the surface of the ocean? The running water that cuts valleys into the land slopes loses its velocity when it flows into a standing body of water such as an ocean. Since the ocean water is heavier, the fresh water from the land stays on top and flows slowly out over the ocean surface. Some explanation other than river flow into the sea must be sought for the ocean canyons.

The most obvious suggestion is that they were cut by streams at a time when the oceanic slopes were above water. The necessary changes of water level would be no greater than those involved in the elevation of the major mountain ranges of the world, all of which are believed to have been below sea level at one time. There are objections, however, to this explanation. Mountain ranges, which show signs of great rock deformation, presumably accompanying the great uplifts that produced them, are limited to certain regions of the earth, whereas the submarine canyons are known to be virtually world-wide. They even cut deeply into the submarine slopes off areas which geologists believe to have been geologically stable for very long periods, and they exist in oceanic regions where broad shallow shelves bordering the coasts testify to countless millennia of wearing away of the lands by waves at approximately the present sea level. Moreover, canyons are found not only off the borders of continents but also on the submarine slopes surrounding oceanic islands such as Hawaii. Another objection to the river-erosion hypothesis is that the only available evidence concerning the time of origin of the canyons appears to confine them to very late geological time, roughly the last million years. Many geologists have been unwilling to believe that during this period the earth's surface has undergone an all-inclusive revolution such as would be required to account for the cutting of these canyons by river erosion and their subsequent submergence by the oceans.

A number of other hypotheses have therefore been advanced Thus it has been suggested that the sea canyons are due to deformations of the earth crust such as those which produced Death Valley or the Dead Sea Valley, or to submarine springs that might flow out with such force on the ocean floor as to produce excavations; or to the great sea waves that follow some of the submarine earthquakes; or to currents of muddy water which it is thought might flow down the oceanic slopes just as rivers flow down the land slopes.

Many geologists have felt that these hypotheses should be tested by marine investigations rather than by philosophical arguments. At the Scripps Institution of Oceanography investigations of submarine canyons have formed a considerable part of the research program for 15 years. This work has been assisted greatly by grants from the Geological Society of America and in recent years by funds from the immense research activities of the U. S. Navy, made available through the Office of Naval Research, the Hydrographic Office and the Bureau of Ships under contract with the University of California. The results of these investigations have provided the only detailed information concerning the exact character of the canyons. Since it is obviously necessary to know what it is that we are trying to explain before testing the hypotheses, we shall first describe the findings of some of the California investigations.

AS it happens, the Scripps Institution of Oceanography at La Jolla on the California coast is located directly inside the branching head of a submarine canyon. This convenient location has provided a remarkably fine opportunity for canyon investigation. It is possible to walk out on the pier at the Institution, get into a boat and be at work over the canyon within 20 minutes.

The canyon has two principal branches, known as La Jolla Canyon and Scripps Canyon, and many small tributaries. It has been explored by many different methods Extensive depth measurements, repeated at periodic time intervals, have been made along the canyons and ranges. Many samples of the bottom have been taken, some of them with large dredges which dug rock from the ledges on the sides of the canyon. The bottom currents have been measured. Sediments moving along the bottom have been collected by means of traps. And the shallower portions of the canyons have been explored directly by divers. This provided a splendid opportunity to take photographs showing details of the remarkable topography of the underwater canyons in this area.

Scripps Canyon, the northern branch of the valley, has been found to have terraced slopes with an inner gorge resembling, on a somewhat smaller scale, the tributary canyons that enter the Grand Canyon of the Colorado. A section of the bottom of the Scripps gorge,

MONTEREY CANYON has a deep tributary which heads in Carmel Bay. The tributary canyon is a continuation of the flat-bottomed river valley extending to the edge of the water in this drawing. The walls of the canyon appear to be of granite. Samples taken at a depth of one mile in the ocean show sand and gravel on its floor.

showing the base of the rock cliffs on one side and the flattish surface of the mass of sediment which has accumulated on the canyon floor, is shown in the photograph at the bottom of page 43 The diver who took this photograph walked over the floor and climbed out of the inner gorge along a little tributary ravine that led to the terrace above. Walking along this terrace, he found another ravine that terminated as a hanging valley on the face of the cliff. Exactly comparable canyons are found ashore in this area.

The walls of the inner gorge of La Jolla, the southern branch of the canyon, are made of unconsolidated alluvium (stream deposits) instead of rock as in the Scripps branch. They are almost as steep, however, as those cut in the rock. Numerous gullylike tributaries were discovered and followed by the diver. The descriptions and pictures of these showed features remarkably similar to the valleys cut into the same sort of material on shore Farther out from shore, La Jolla Canyon was found to have rock walls, but no indication of vertical cliffs has been discovered there as yet.

ANOTHER California canyon that has been extensively studied heads into Monterey Bay. This canyon can be traced outward to depths of two miles below sea level. In one place a cross section of it proved to be closely similar to that of the Grand Canyon. Monterey Canyon has a large tributary that enters Carmel Bay. Detailed soundings of this branch showed that it is an underwater continuation of a land canyon of the same type (*drawing on page 41*). The walls of the submarine section of the Carmel Canyon are of granite, and the same type of rock was found on one wall of the main Monterey Canyon. The floor of Monterey Canyon has a variety of deposits. Rounded gravel was found in one core sample out in depths of about one mile. Elsewhere sand was found at various depths. Since gravel and sand are considered to be deposits of shallow-water origin, these canyon-floor deposits may have considerable significance.

Currents measured on the floors of the canyons off the California and New England coasts proved to be weak eddies which flow slowly up and down the canyons, reversing direction in many cases at intervals of an hour or less. No evidence has been found to indicate that these currents are strong enough to be capable of even removing the sediment that is being carried out into canyon heads by wave action. So much sediment is carried into the canyon heads that, if nothing interfered, the inner portions of the canyons would be largely filled in a few hundred years. Repeated exact measurements of the profiles across the canyon heads revealed why the canyons have not been filled up. It was found that the fill on the canyon floor is at least partially flushed out from time to time by large landslides or mudflows. The slopes of the canyon axes are sufficiently steep so that such slides are by no means surprising. In some cases where piers have been built out into the heads of canyons, the sliding of the bottom material towards the outer canyon has removed the support from the pier pilings and caused the ends of the piers to collapse.

The preceding description is based entirely on work in the California canyons, which have been particularly well explored, but there is no reason to believe that these canyons are unusual. The available information indicates that coastal submarine canyons are virtually the same the world over. Therefore we are probably not making a mistake in applying this localized information to a general analysis of the canyon problem.

Applying the knowledge obtained from the California investigations, let us consider the various hypotheses suggested for the formation of submarine canyons. First, the theory that they were created by rifting or faulting of the earth's crust is unsatisfactory for many reasons, it is not now seriously considered by geologists Typical fault valleys, such as Death Valley, have relatively straight walls and broad, flat floors. They lack the branching tributaries, the V-shaped cross sections and the winding courses that typify both the submarine canyons and the land canyons.

If submarine springs were important in the formation of canyons, there should be many deep basin depressions along the courses of the canyons and they should have walls consisting to a considerable extent of cavernous limestones. Nothing of this sort has been found in the exploration of submarine canyons. Furthermore, the conditions allowing active submarine water circulation apparently do not exist in most areas where submarine canyons have been found.

The great sea waves, known popularly as tidal waves and by scientists as tsunamis or seismic sea waves, have a powerful erosive effect on the shores that they strike at rather rare intervals. According to long-established laws in wave mechanics, however, the violence of these waves must decrease rapidly with increase in depth, so that only extremely small currents could be expected at the great depths to which submarine canyons have been traced. Moreover, the canyons represent depressions in the sea floor, whereas tidal waves are known to produce their maximum effects on underwater elevations and minimum effects in depressions. As a clinching fact, in the belts where tidal waves are most common, submarine canyons are rare.

The idea that muddy water can run down submarine slopes and cut canyons has been held by a considerable number of geologists In fresh-water lakes, currents of muddy water are known to flow down the fronts of deltas being built up by rivers. These currents, known as density currents or more properly as suspension currents, are due partly to the greater density of the colder water of the entering rivers and partly to the sediment load they carry. Yet even in lakes the suspension currents fail to produce erosion They inhibit somewhat the deposit of sediments on the deltas, but the shallow channels that result from this slower rate of deposition are a far cry from the submarine canyons thousands of feet deep which are cut into solid rock. And in the ocean, as we have noted, the inflowing river water is not heavier but lighter than sea water, so it does not flow down the slopes.

WE are thus left with only one hypothesis, namely, that the areas where the canyons are found were once above water and were eroded by rivers in the same way as the present land canyons. There are many reasons for believing that rivers are the cause The almost perfect resemblance between the river canyons of the land and those of the sea floor is a powerful argument by itself. The extension of the heads of a considerable number of submarine canyons into the long arms of the sea at the mouths of rivers is inexplicable under any hypothesis except that of river erosion, as even the authors of other hypotheses admit.

Perhaps the strongest evidence is the fact that many of the largest submarine canyons are found off the mouths of large rivers. For example, the largest canyon in the Gulf of Mexico is located off the Mississippi Delta. One of the largest canyons off the U. S. West Coast lies directly off the mouth of the Columbia River. A huge canyon extends into the bay at the mouth of the Congo River in west Africa, and canyons are found off the deltas of the two largest rivers of India, the Ganges and the Indus.

If the river-erosion hypothesis is correct, there has been an enormous submergence of the borders of the continents in what is considered geologically as a relatively recent period. Hence one should expect to find many other indications of this submergence besides submarine canyons. This expectation is definitely fulfilled. For example, off southern California there is a series of islands separated from the mainland by wide channels from a thousand to several thousand feet deep. Among the animals on these islands are such mammals as foxes, which could scarcely have crossed the intervening water areas. Many of these island animals are slightly different from their mainland relatives, and are therefore classified as endemic species or subspecies. Their special characteris-

tics indicate that they have been separated from the mainland populations for a considerable period, probably many thousands of years If these islands once had land connections with the mainland, as the presence of the animals indicates, the land elevation required would be sufficient to support the theory that the submerged canyons off southern California were cut by rivers.

Dredgings from banks and sea mountains with summits thousands of feet below the present sea level have yielded rounded cobbles. Clearly this rounding must have taken place when these deep submarine mountains were exposed to the full force of breaking waves. Less direct evidence comes from the deep, flat-topped sea mountains, or guyots, which have been found in large numbers in the Pacific and less commonly in the Atlantic. These flat surfaces suggest that the tops of the mountains were once at or near the surface so that their peaks were worn off by waves or, in the case of some of those found in the tropics, became the site of coral-bank formation. There is as yet no good evidence of the age of these banks.

Another type of evidence of great submergence, which may or may not have any relation to submarine canyons, has been found in the coral atolls. In all of these in which deep drillings have been made, the material underlying the atolls has been found to contain shallow-water organisms very like those now found either in the encircling reefs or in the lagoons within the reefs.

In view of the accumulating evidence of great submergence which is so clearly indicated by the world-wide distribution of the submarine canyons, we are forced to conclude either that this evidence is all very misleading or that tremendous changes have actually taken place. It is possible that all or most of these changes have been due to shifting sea levels. To be sure, it is difficult to find any way to get rid of the vast amount of sea water that is demanded by a subsidence of the oceans of such dimensions. Could the glaciers of the Ice Age have been big enough to take care of a large part of the oceans by piling up the water on the land to the height of many miles? Most geologists doubt it. Yet even this radical idea may prove to be the explanation. Alternatively, one might conceive that the continents and ocean basins have undergone vast shifting movements that temporarily exposed the margins to river erosion. The implications of these ideas are revolutionary. They may lead to radical changes in supposedly well-established geological concepts.

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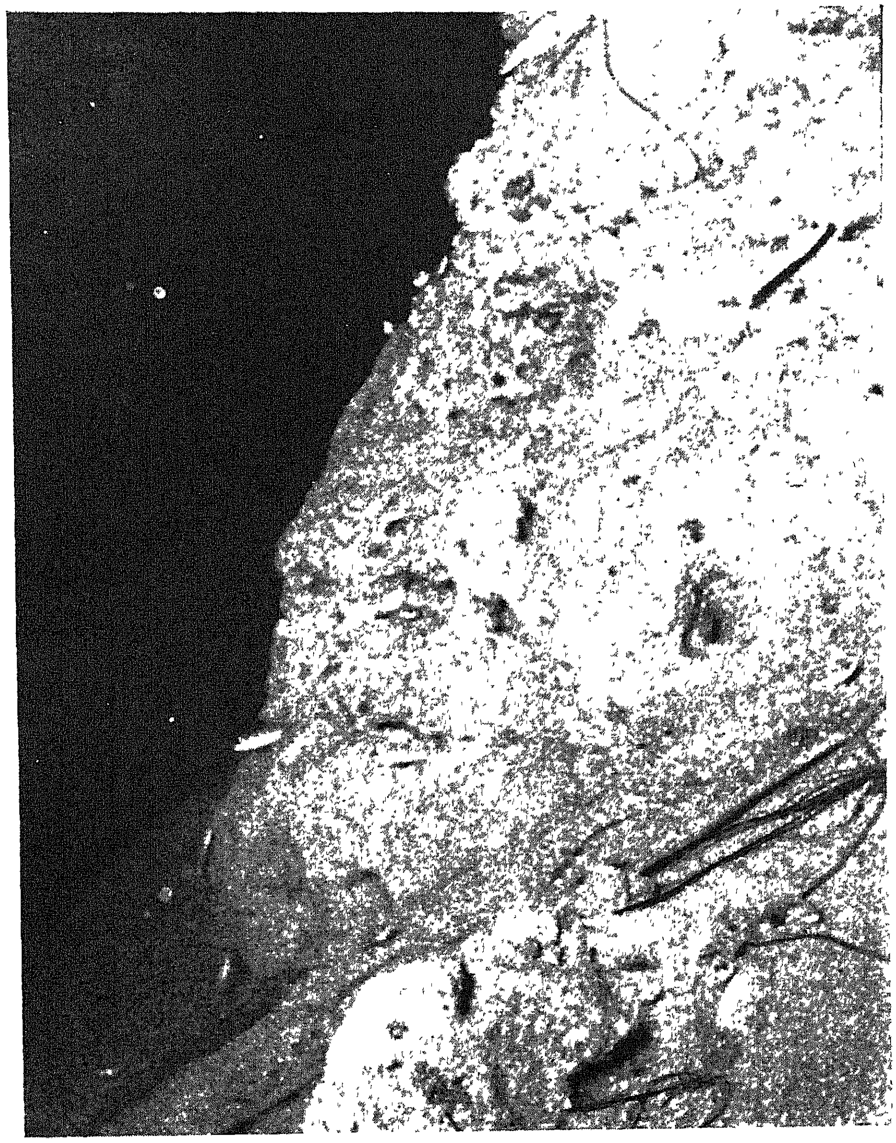


CLIFF cut into an alluvial formation at the head of La Jolla Canyon is almost vertical. This photograph and the photograph below were made by a diver exploring bottom under direction of the Scripps Institution of Oceanography.

ROCK WALL of the Scripps Canyon is photographed from the canyon floor. At the bottom of the photograph is an accumulation of kelp and eel grass. The round holes which appear in the rock were made by boring organisms.

Greek Astronomy

How the imaginative Hellenic philosophers found the solar system and then lost it is one of the enthralling stories of early scientific thinking

by George de Santillana

THE Greeks are a fascinating people to study because they were ingenious. As scientists they possessed little equipment except their imagination, logic and vast curiosity; with these gifts they managed to clear away much of the rubbish of primitive mythology and begin man's first intelligent and systematic thinking about the universe. And of all episodes in the protracted but exciting birth of science none is more enlightening than the curious story of the Greeks' attempts to explain the astronomy of the Earth and its companion solar system.

The study of astronomy did not, of course, originate with the Greeks. The Egyptians and Babylonians had mapped the heavens and even charted the courses of the planets, but they were observers rather than analysts; they were content to describe the heavenly sphere as a canopy of fixed and moving stars without troubling themselves about the mechanism that regulated it. The Greeks from the start tried to explain, or, as they said, to "render account."

Curiously, until the Homeric period and even beyond it they ignored the planets, the "wanderers." Unlike the men of the East, who were searching for signs, the Greeks were immune to astrology until very late in their history. They brought to the skies the practical interest of farmers and sailors. They used the stars for navigation, and they knew from the rising and setting of the constellations the times for sowing and for harvest, for setting out to sea and for putting up their boats. Their earliest efforts to account for the cosmos were naturally in terms of mythology. From Erebus—Darkness or Old Night—were born Aether and the Day. From Chaos were born the Earth and Eros, the most beautiful of the gods. The Earth bred the Mountains, the Sea and Uranus, the Sky. The mating of Earth and Sky produced the first mortals—the Titans and Cyclops. Other early seers pictured the Earth as a great Tree of Life floating in the skies, decked with the shining mantle of the starry night; still others spoke in colored words of the great Egg from which all things were born. These poetic explanations were not very different from the Hindu cosmologies, which held that the Earth was borne on the backs of 12 great elephants that stood on the back of a turtle swimming in the universal sea. Such was the normal thinking of all antiquity as it emerged from its primeval dreams.

The first assay at a rational theory was made by the sage and statesman Anaximander, who in about 550 B.C suggested the daring idea that the Earth was at the center of the world, poised in a void, because, as he said, there was no reason for it to fall one way more than another. The great ideas that were to shape Greek astronomy and mathematical physics were formulated half a century later by Pythagoras and his pupils. They argued that the stars obeyed the laws of numbers and that their courses must satisfy the requirements of geometrical beauty. All heavenly bodies must move in perfect circles at a uniform rate, for that was the only motion befitting their eternity and perfection.

THE WILD, free imaginations of the Pythagoreans helped to liberate and stimulate Greek thinking about the "cosmos"—meaning beautiful order. To one Pythagorean, Okellus of Lucania, we owe the prophetic idea that "the stars must be worlds like ours with animals and plants on them and possibly even people." The century or so after Pythagoras' death harvested some of the greatest discoveries of the Greek mind: the creation of logic, the corroding criticism of the Sophists, the subtle paradoxes of Zeno explaining continuity and the relativity of movement, the theory of a world made up of nothing but "atoms and the void."

By Socrates' time, about 450 B.C., Philolaus the Pythagorean had come forward with the first coherent theory of planetary motions. Philolaus introduced the idea that the planets moved across the heavenly sphere in a sense retrograde or contrary to that of the sphere as a whole. His scheme pictured the Sun and the planets revolving in concentric circles beneath the heavenly canopy.

Combining sound scientific reasons and metaphysical intuition, Philolaus resisted the impulse to put the Earth at the immovable center of things. He found it unthinkable that our messy Earth should be at the center of all this perfection. Only pure Fire, of the same nature as the heavenly Fire, was a fit center for the cosmos, and the Earth, like the other planets, revolved around the Central Fire in a period of 24 hours. As a body in the heavens, where roundness is the rule of perfection, the Earth of course was round, as Pythagoras had suggested, and this explained the roundness of its shadow in eclipses of the Moon.

Yet there was a flaw in the perfection that had to be explained. In the Pythagorean arithmetic, the sacred number was 10. Even including the Earth as a heavenly body, the circles in the system added up to only nine. Hence the Pythagoreans had to postulate the existence of an additional planet, closer than the Earth to the Central Fire and similarly endowed with a period of 24 hours. The Earth always showed the same face to the Central Fire, and since this face was the antipode to the inhabited side of the Earth, both the Anti-Earth and the Central Fire were invisible to us.

Such was the strange mixture of science and fantasy that constituted the first human attempt to picture the solar system. Some of Philolaus' immediate successors seem to have tried to reduce the system to greater scientific simplicity. But even with its modifications the Pythagorean system, in all its perfect roundness, did not fully convince the Greeks. They had observed, for instance, that the Sun and the planets did not move uniformly in perfect circles. Unable to bring themselves to abandon the symmetry of the circle, they attempted to rationalize the problem. Thus Plato put the question in this form: "What are the circular and perfectly regular movements which we should suppose so as to be able to save the appearances presented by the wandering stars?" Endeavoring to answer his own question,

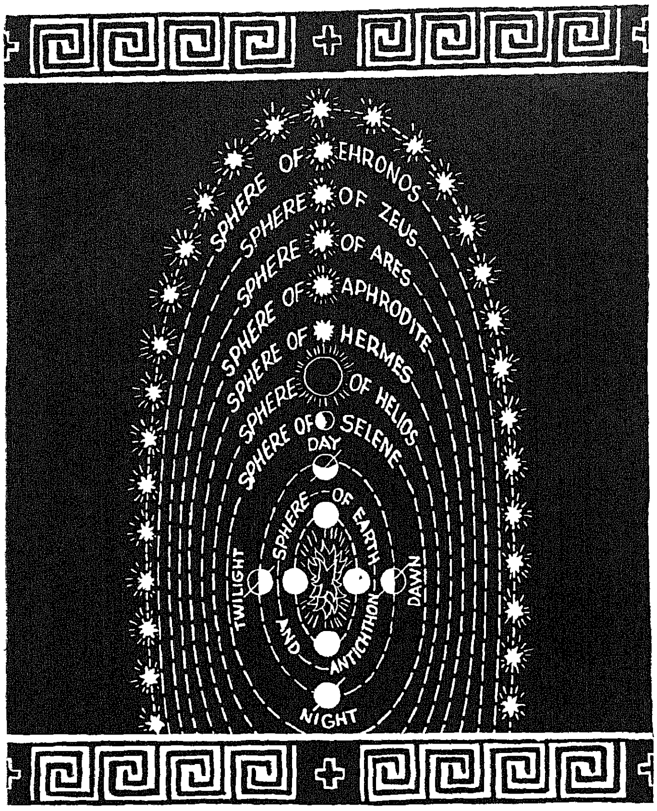
he built one of the most fascinating and complicated models that a metaphysician could imagine, mixing up astronomy with his theory of the soul.

MEANWHILE, professional mathematicians among Plato's friends sought a purely mathematical theory to account for the planetary movements. The greatest of them was Eudoxus, the author of the fourth book of Euclid and famed for his introduction into geometry of what we now call mathematical rigor. Eudoxus knew that the planets described paths upon the sky that looked more like the curlicues of a cosmic Saul Steinberg than like precise geometrical drawings. He set out to master the problem by an expenditure of geometrical ingenuity that has rarely been equaled. His system, when he completed it, had no resemblance to any mechanical model ever made on earth. The movement of each planet was composed of four circular, uniform components. One was a 24-hour rotation of the sky as a whole; the other three were equivalent to a lemniscate (shaped like the figure 8 lying on its side) carried around on the plane of the zodiac. This figure-8 track accounted for all the varieties of the observed planetary movements, but his "homocentric" system as a whole, consisting of five planetary systems of spheres that fitted inside one another, defied any material representation, for the 24-hour revolution of the skies could not be transmitted mechanically to the inner spheres.

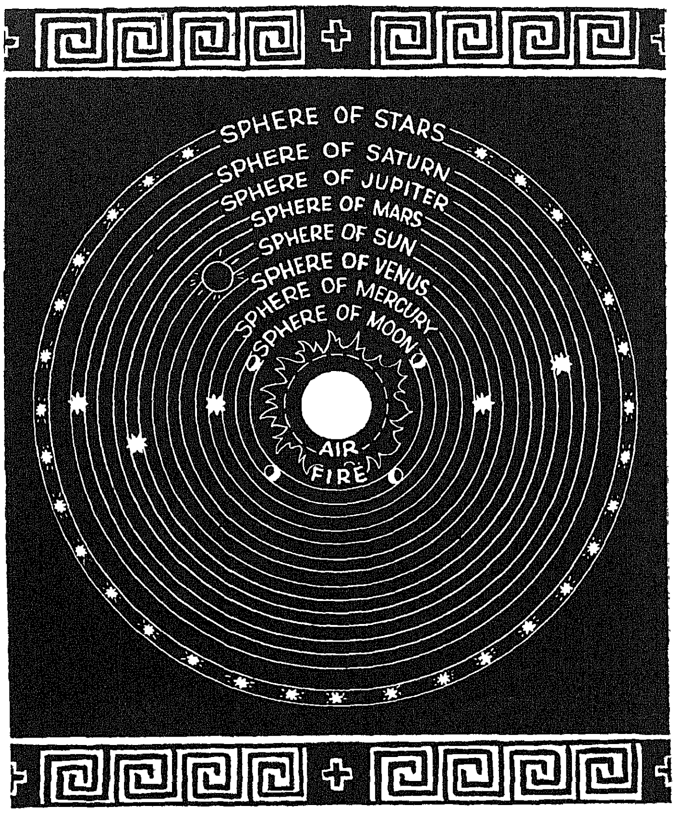
A new idea was needed. That idea was supplied by a philosopher little known to us but highly esteemed among his contemporaries—Heraclides of Pontus. He noticed that Mercury and Venus, unlike the other planets, have a strange habit of never getting very far from the Sun. He suggested, therefore, that those two planets actually revolve around the Sun, which in turn revolves around the Earth. This theory, however, left the behavior of such a planet as Mars unexplained. We do not know who tackled that more difficult problem, but it seems to have been the Pythagoreans of that time. Their idea was this: Mars moves in an orbit eccentric to that of the Earth, and its greatest splendor occurs when it is in opposition to the Sun and nearest to the Earth. Because the oppositions of Mars do not always take place in the same section of the zodiac, the center of its orbit must shift around (very much as a cam revolves on a camshaft in a modern machine). The center of Mars' eccentric orbit seemed to be always in the direction of the Sun. Why not, then, identify this center with the Sun itself? And if Mars, as well as Venus and Mercury, moved around the Sun, why not the other planets too, even if their eccentricities were less observable?

The solar system—or rather, a solar

PTOLEMY'S SYSTEM, depicted here in a medieval drawing, had Earth at its center with other planets and Sun circling it. In successive orbits outward are the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn. Though not quite satisfactory, this scheme seemed to account for observations of planet motions in the sky.



PHILOLAUS' SYSTEM, first attempt to explain the universe, showed spherical Earth revolving around Central Fire, with Anti-Earth (Antichthon) to round out perfect Pythagorean number of 10 heavenly bodies.



CRYSTAL SPHERES theory, suggested later, held that the Sun and planets were carried on revolving, transparent crystal shells, which turned in concentric circles around the Earth as the center of the entire system.

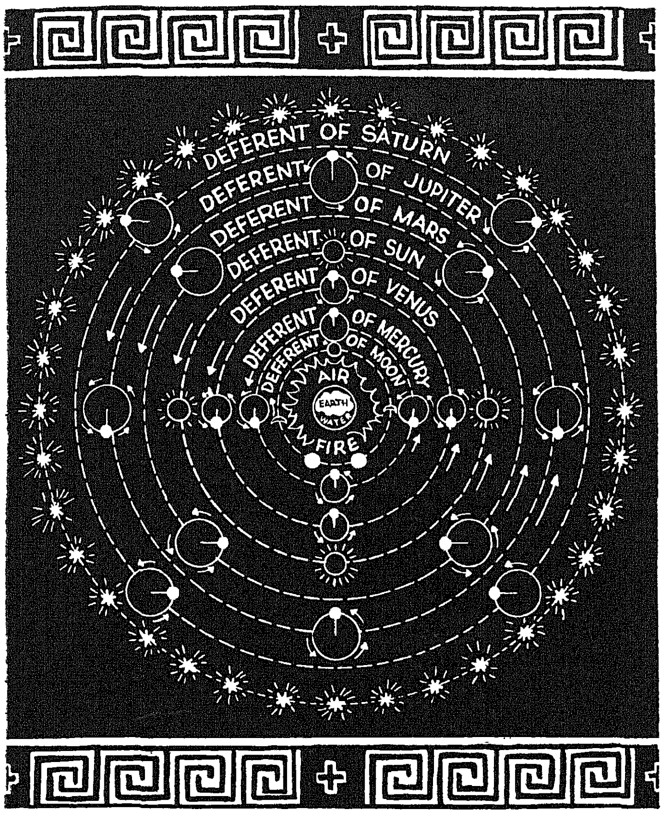
system—had been born. Of course it was a solar system in which the Sun still revolved around the Earth. The system did not look very rational on paper; it certainly did not look elegant enough to satisfy the Greek instinct for symmetry. The system was tangled up in a confused mesh of movements. the inner planets described epicycles centered in the Sun, the outer ones, eccentrics which threw loops around the Earth. The whole thing was distasteful to the official schools of philosophy and to the mathematicians.

Yet the problem was ripe for a simple, daring answer, and the Greek imagination did not fail to find it. The answer was suggested by Aristarchus of Samos. The apparent difference in the orbits of the inner and outer planets, he said, is simply one of observation. The inner planets clearly revolve around the Sun; the orbits of the others are less clear only because their radii are greater than the distance of the Sun from the Earth. Aristarchus had calculated by geometrical methods that the diameter of the Sun was about six to seven times as great as that of the Earth, which meant that the Sun's volume was some 300 times that of the Earth. Even without any knowledge of gravitational dynamics, it must have seemed unnatural that the larger body should revolve around the smaller one. What if the distance of the Earth from the Sun is really the radius of the *Earth's* orbit, not the Sun's? Then, said Aristarchus, the Earth would find its natural place as a planet between Venus and Mars, where we would expect it to be. Simplicity is regained, common sense is re-established, and there is nothing but a series of concentric circles around the Sun, with only the Moon left revolving around the Earth.

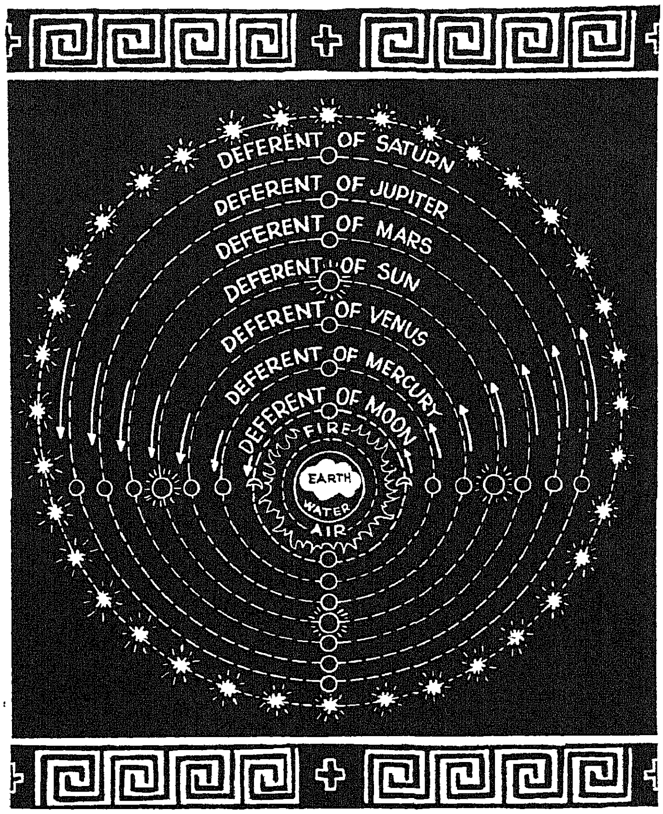
SO HERE was the Copernican system, published in the year 270 B.C., 18 centuries before Copernicus. Had the Greeks accepted it, no one can know what the consequences might have been—for science, for politics, or for Christianity. But Aristarchus had made his suggestion at the wrong time. If the limpid Pythagorean concentric circles had still been considered adequate, Greek astronomers might have given in. But they knew already that the circles could not be as concentric as the Pythagoreans had supposed. New observations had changed the shape of the orbits.

To begin with, it was now realized that the distance of the Sun from the Earth was not constant, for measurements had shown that the apparent diameter of the Sun varied with the seasons. Furthermore, the orbits of the planets had been found too erratic to be described by perfect concentric circles. Above all, an apparently conclusive objection was voiced by Archimedes, a younger contemporary of Aristarchus. Archimedes liked to deal with big numbers, and he had noticed, as had most of his contemporaries, that the universe of Aristarchus needed very big numbers indeed: it had already been estimated that the distance of the Sun from the Earth was certainly greater than 14,000 earthly diameters. If the Earth described so large a circle around the Sun, then at different places in its orbit small shifts in the relative positions of the fixed stars should be observed. But no such shifts could be detected. This is not surprising, for the Greeks had no instrument capable of measuring these tiny displacements. The parallax of the nearest visible fixed star, Alpha Centauri, which was not measured until 1830, is only .756 seconds of arc.

Aristarchus actually guessed the reason for the failure to detect these shifts: namely, the great distance of the stars from us. He said: "The circle of the Earth's orbit is so small with respect to the sphere of the stars that the whole orbit is in the same relation to the heavenly sphere as the center is to the circumference." Archimedes, making no effort to understand what Aristarchus could have meant by this statement, dismissed it as nonsense, on the ground that a center obviously could have no dimensions. The idea of a solar system lost in the immensity of the heavenly void was unacceptable to his Greek sense of fitness and proportion. Why postulate this unheard-of, absurd infinity? Infinity was a concept



EPICYCLE THEORY was devised to explain varying distances of planets from the Earth. As they traveled in their main orbits, called "deferents," the planets also revolved in the shifting smaller circles called epicycles.



ECCENTRIC SYSTEM was another attempt to solve same problem. It accounted for the retrogression of the planets, but it dissatisfied many of the Greeks because it displaced the Earth from the exact center of the circle.

abhorrent to the Greeks, they identified it with something that was not good enough nor formed enough to have a shape and a definition. Aristarchus' guess was too incredible to be accepted by Greek opinion of the time.

Aristarchus had just come too late. The great creative period of Greek thought was over. The last Pythagoreans had become numerologists and magic-mongers. The most popular schools of philosophy—the Stoics, the Epicureans and the other moralists—had little interest in science. Their teaching was aimed mainly at helping men to save their self-respect in an increasingly meaningless world. Great kingdoms had been born from Alexander's conquests. Oppressive state machineries and threatening world wars directed men's thoughts to the only reasonable hope—the One World idea of the time. It was soon to come, in the shape of the Roman Empire, and with it a frozen stillness, the absolute zero of thought.

THERE WAS still, of course, good special science. Greek antiquity had its equivalent of Tycho Brahe, the great 16th-century observer whose observations provided the foundation for Kepler's laws of planetary motion. He was Hipparchus of Bithynia, who came a century after Aristarchus. He set up a catalogue of 1,120 stars, observed the first certified nova in history, invented the first trigonometry, built an instrument (called the *dioptra*) which was something like a modern transit without a telescope. He restricted himself to making observations for a more precise description of the Earth-centered system. He seems to have had a working scientist's distrust for all philosophical assumptions. If you had asked him whether the system was "true," he would have answered, with slightly raised eyebrows, that the question made no sense—all that counted was that it "worked."

And work it did, at the price of further and further complication. By the time of Ptolemy, the last great ancient astronomer (140 A.D.), all pretense of simplicity had been abandoned. Yet the unwieldy complexity of the Ptolemaic *system should not obscure the strictly* scientific nature of the work on which it was based. When we are tempted to smile at the Greeks' epicycles, we should remember that in our astronomical theory we are using not a baker's dozen of them, as the Greeks did, but hundreds and thousands. They are tucked away in a line of calculus, under the name of periodic terms—which apparently makes them less embarrassing.

The Greeks had a clear idea of the task of mathematical analysis, even though they had only one instrument with which to implement it—simple geometry. What they were able to accomplish with their little circles can be seen by comparing the modern data for *the greater semiaxes of the planetary* orbits, that is, the maximum distances of the planets from the Sun, with the corresponding numbers in Ptolemy. In the Ptolemaic system these computations are expressed as the ratios of the radii of the epicycles to those of the deferents. The comparative figures, with the Earth's greater semiaxis taken as one, are:

	Modern	Ptolemy
Mercury	0.387	0.371
Venus	0.723	0.719
Mars	$(\frac{1}{a})$0.656	0 658
Jupiter	$(\frac{1}{a})$0.192	0.192
Saturn	$(\frac{1}{a})$0.105	0.108

The Ptolemaic system remained frozen *for 14 centuries, until Copernicus, re*-discovering and drawing upon the then dim traditions of Aristarchus and the earlier Pythagoreans, found the courage to challenge it. Copernicus' theory also might have been sidetracked, had not Galileo come along to confirm it with his telescope and his system of dynamics, which had its origin in his rediscovery of Archimedean mechanics. So the solar system, once found and lost by the Greeks, was found again.

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TITANIUM: A NEW METAL

Nearly as strong as steel but only half as heavy, it will soon join iron and aluminum, metallurgists believe, as one of the three most important metals

by George A. W. Boehm

TITANIUM is a rather common element that has been known for more than 150 years. It is the ninth most abundant element in the earth's crust—more than 20 times as common as carbon, more plentiful than lead, copper, tin and half a dozen other metals combined, outranked among the metals only by aluminum, iron and magnesium. Yet as a useful metal titanium has been discovered only within the past decade.

It now seems to be on the threshold of a brilliant career. Pure titanium is a silvery metal which looks and behaves like stainless steel, but is little more than half as heavy. It is much lighter than iron, much stronger than aluminum, almost as rustproof as platinum. Although it is not preëminent in any single quality, it combines the best features of many metals; like an Olympic decathlon champion it is outstanding in all-round ability. The metal has certain drawbacks: it will never be as cheap as steel, and its refining, casting and fabrication present difficulties. But its combination of light weight and strength and its exceptional resistance to corrosion make it ideal for a great variety of uses, from pen points to engines and aircraft frames. Metallurgists and engineers believe that titanium will soon become one of the world's most important metals.

Titanium is a "new" metal because it has only recently been refined sufficiently to reveal its properties. It is still being produced only on an experimental basis, at the rate of a few hundred pounds per day. But the metal is under investigation in some 100 laboratories, and the investigators are almost uniformly enthusiastic about its possibilities. Their studies of course include the alloying of titanium with other metals. Since pure titanium is comparable in strength and wearing qualities with stainless steel, its alloys should be truly remarkable.

Titanium will not replace iron or aluminum, but it will bridge the gap between them. The three metals will form a complementary trio. Iron and steels are strong and cheap, but not light. Aluminum alloys are light and cheap, but not particularly strong. Titanium alloys will be light and strong, but not cheap. Thus titanium will be reserved for the many applications in which its exceptional combination of qualities outweighs price considerations.

TITANIUM was discovered in 1791 by William Gregor, an English clergyman and amateur chemist, who identified compounds of the metal in the black sands of Cornwall. A few years later the German chemist Martin Heinrich Klaproth, now famous as the discoverer of uranium, rediscovered Gregor's element in an ore called rutile He named it titanium after the Titans, who in Greek mythology were the sons of the Earth.

The richest ore of titanium is a black oxide mineral called ilmenite, after the Ilmen Mountains in Russia. Ilmenite is also rich in iron. For hundreds of years this ore had been mined in the Ilmen Mountains for its iron, the titanium being discarded as an unwanted impurity. But at about the end of the 19th century the first use was found for the element. The aluminum and steel industries began to employ extremely small amounts of rather impure titanium as an alloying ingredient. In this form titanium was so brittle that it bore a closer resemblance to rock than to metal. A fraction of one per cent of titanium was found, however, to refine the crystal structure of some steels and aluminum alloys, thus endowing the metals with greater toughness.

A more important use, which gave birth to a new industry, was discovered in 1908. Dr. A. J. Rossi of the Titanium Alloy Manufacturing Company prepared some white titanium dioxide (TiO_2) and mixed it with vegetable oil to make a white paint. He found that the compound made an excellent white pigment. In 1926 a process was developed for manufacturing a pure grade of titanium dioxide, and industry began to take a great interest in the material. As a pigment it is outstanding for its opaqueness, or hiding power. One pound of titanium dioxide will cover a larger area than five pounds of lithopone, a very good pigment made of zinc and barium. Since the war titanium dioxide has increasingly replaced white lead, which is now hard to obtain.

Titanium dioxide is also useful in conserving paper When impregnated with this dense pigment, the thinnest grades of paper are opaque and can be used for Bibles and air-mail stationery. Large amounts of it are rubbed into rayon to dull its natural gloss. Today the production of titanium dioxide in the U. S. is an estimated 225,000 tons a year. The material is so important that it has recently been the subject of an antitrust order by the courts.

The infant titanium metal industry as yet is only a tail on the kite of the pigment industry. Chemists are still struggling with the problem of refining the metal. The mining of titanium offers no particular difficulties Rich deposits of ilmenite are already being worked in New York, Virginia and North Carolina, and certain black beach sands in Florida and Oregon are excellent sources of the element. Perhaps the most promising deposits on the North American Continent are those in the Province of Quebec.

In theory, the refining of titanium is simple enough. As worked out by Dr. Wilhelm Kroll, a metallurgist from Luxembourg, the process involves separating titanium from its accompanying iron in impure oxide form, and treating it with chlorine to form titanium tetrachloride, a volatile liquid. This compound is then mixed in a closed iron chamber with metallic magnesium, which because of its greater chemical activity preempts the chlorine, reducing the titanium to the metallic state. The final step is to get rid of the magnesium chloride and any excess magnesium metal, either by evaporating them by heating in a vacuum or by washing the mixture with hydrochloric acid, which dissolves the magnesium. The process yields titanium in a gray sponge form, which is then melted and cast into ingots.

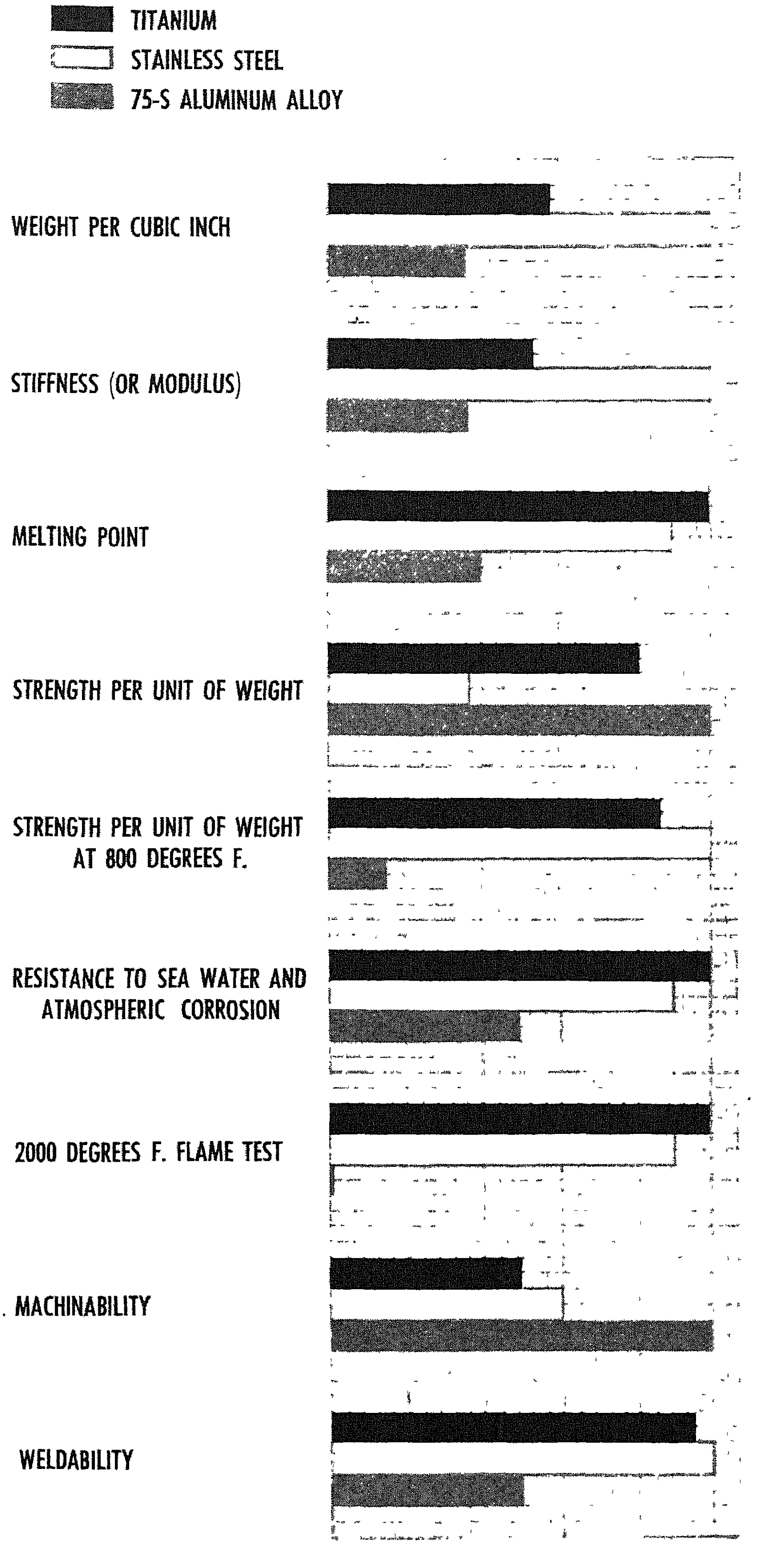
In practice, however, titanium refining is attended by problems at every step. The metal is hard to handle on heating, for at high temperatures it becomes extremely active. It greedily absorbs oxygen and nitrogen from the air. And as little as one per cent of these gases utter-

ly destroys the ductility of titanium, rendering it as brittle as pumice. So at every stage of processing, titanium must be protected from air, either by a blanket of inert gas (*e.g.*, helium or argon) or by a vacuum. Moreover, the step in which titanium tetrachloride is reduced with magnesium presents another difficulty. If the temperature is not carefully controlled and kept below 1,600 degrees Fahrenheit, the titanium attacks and dissolves the walls of the iron reaction chamber. Control of the temperature is complicated by the fact that the reaction gives off a tremendous amount of heat, and titanium is a relatively poor heat conductor, thus it does not appear possible to draw off the heat fast enough unless small reaction chambers are employed. This will probably restrict the production of titanium to 250-pound batches, unless a method radically different from the Kroll process is devised.

THE most exasperating difficulty of all is that of melting the purified metal sponge to cast it. One metallurgist who has been struggling with titanium asserts that the problem of producing the pure metal at low cost is just that of melting it cheaply and in large quantities. Titanium melts at 3,140 degrees F. It is melted in an electric furnace, and of course must be handled in a vacuum or an atmosphere of inert gas. However, in its molten state titanium not only absorbs nitrogen and oxygen but dissolves crucibles and furnace linings made of the common resistant materials. Glassy oxide furnace linings such as aluminum oxide, which are used to hold other molten metals, are ruinous to titanium. Even the most stable of these materials yield their oxygen to the avid metal. Current research on this problem points to dense carbon crucibles as the most satisfactory. Small quantities of carbon in themselves do titanium no great harm. But since the total amount of impurities that can be added to titanium without seriously impairing its ductility is strictly limited, another crucible material must be used when carbon is not to be a final constituent of the titanium alloy.

The Battelle Memorial Institute of Columbus, Ohio, has developed a technique for melting titanium without contaminating it. The crucible is a copper hemisphere. The key to the success of this method is a bath of cold water surrounding the crucible. Metallurgists at Battelle have found that molten titanium does not wet cool copper, it stands aloof from the surface of the copper like water on a duck's back. This method, however, has certain difficulties, and some metallurgists doubt that its cost can be reduced sufficiently to make it generally applicable.

Still another possible crucible material is thorium oxide. Like other oxides,



TITANIUM'S PROPERTIES, here compared with those of stainless steel and an aluminum alloy, make it an almost ideal metal for most purposes. Its usefulness will be limited only by cost and some difficulties in production.

the material contaminates the molten titanium, but in this case the contamination may prove to be welcome, for preliminary tests indicate that a trace of thorium greatly reduces titanium's unseemly appetite for oxygen

Once it has been melted and cast into ingots, titanium need no longer be kept in a vacuum. It can without difficulty be forged, hot-rolled, cold-worked, drawn into wire, extruded as tubing, or machined. When it is kept above about 1,300 degrees F., however, titanium must be sheathed between sheets of steel to keep it from absorbing oxygen and nitrogen. In general it is handled like other metals; indeed, its mechanical properties are so similar to those of stainless steel that it can be fabricated with the same equipment with only minor adjustments. After prolonged heating, titanium acquires an extremely hard, black surface scale which must be removed by grinding with carbide tools, but otherwise it is no more difficult to drill and cut than stainless steel. While no way has been found to braze or solder titanium or to weld it to metals other than itself, the metal has excellent shear strength Thus titanium rivets are strong, and rivet holes in sheet titanium also hold their shape under great stress

But it is on titanium's alloys that metallurgists pin their hopes. There is good reason to believe that these alloys will be as far superior to pure titanium as special steels are to iron. The metal is presently being blended with virtually every other element in the periodic table. The results so far are fragmentary, but one positive statement can be made: alloys for structural use will all be titanium-rich, containing not more than about 10 per cent of other elements. This limit is necessary because the ductility of titanium is so sharply reduced by any other substance.

THE first large-scale use of titanium will probably be in the aircraft industry. Because the light metals aluminum and magnesium lose their strength at temperatures much above 350 degrees F., aircraft designers must use more and more steel in modern high-speed planes. Yet every pound of extra weight adds an estimated $25 to $250 to the fuel cost during the life of the plane. Wherever titanium replaces steel, it can cut the weight by 40 per cent. On this basis titanium in planes would be economical at two or three times its present cost.

Titanium is strong and elastic up to about 800 degrees F. Above that point it weakens rapidly, and prolonged exposure to temperatures greater than 1,000 degrees causes the metal to soak up embrittling oxygen and nitrogen. It should be possible, however, to alloy titanium so that it will behave better at high temperatures. Some success in this direction has already been achieved Ironically it has been found that titanium's performance at high temperatures is greatly enhanced by alloying it with small amounts of aluminum. Titanium has a low coefficient of thermal expansion—about half that of most steels. It also retains its strength and flexibility at subzero temperatures, an important consideration in high-flying airplanes.

Titanium has already been suggested for a wide variety of other applications in industry and consumer goods. Its resistance to expansion and contraction makes it useful for precision parts in instruments, it will stay within prescribed tolerances over a wide temperature range. Because it can be surface-hardened to a remarkable degree, it is an ideal material for spindles in cotton mills, where the continuous rubbing of thread rapidly erodes most metals except hardened steel, which is heavy and consumes a great deal of power Titanium is impervious to the most corrosive foods—cider, vinegar, onion juice, pineapple juice, lard, tea, coffee, grapefruit juice—and so it is a promising candidate for pipes and tanks in food processing plants Many of the strongest acids and alkalis, even when hot and concentrated, have no effect on titanium. There is a strong possibility that its remarkable inertness will make titanium suitable as a replacement for bone and cartilage in medicine. Several surgeons are now testing titanium's biological acceptability by implanting the metal in living bodies. If muscular tissue adheres to the metal and no irritation is set up, titanium may replace tantalum and silver for this purpose. Titanium's light weight should be a great asset in this application.

Some enthusiastic naval officers envision an entire battleship built of titanium. The Navy is perhaps titanium's most ardent admirer, for the very good reason that titanium has a truly amazing resistance to salt-water corrosion. The results of one experiment show why the Navy is excited. A sheet of titanium was hung half-submerged in the ocean and buffeted by a thin, fast jet of sea water. After two months of this rough treatment, the titanium was removed. The experimenters had neglected to mark the piece of metal, however, and the titanium was so clean that they were unable to tell on which side the jet had played. All other metals except platinum and Hastelloy C disintegrate during this test, and the Navy is not anxious to rely on Hastelloy C, which is composed largely of the critical metals nickel and chromium.

Alloy research on titanium is hampered by uncertainty because of the slight impurities present in the "commercially pure" metal. Variations of the Kroll process followed by careful melting yield 99.5 per cent pure titanium But the metal's properties are so greatly altered by the little remaining iron, manganese, oxygen, nitrogen and hydrogen that metallurgists must turn to an even purer form in order to isolate the effects of added alloying ingredients. For research purposes they have refined it to a form known as iodide titanium which is more than 99.99 per cent pure It is made by plating titanium from titanium iodide vapor on an incandescent tungsten wire. Iodide titanium varies in price from about $200 to roughly $3,000 a pound, depending on the difficulties encountered in a month's processing. The iodide process is important for metallurgical research, but as an industrial production method it is out of the question.

TITANIUM'S chemical activity is its greatest weakness and at the same time one of its most attractive properties Its suicidal affinity for gases when hot, and for virtually everything when molten, makes titanium inherently difficult and expensive to process On the other hand, its inertness when cool will enable titanium to replace aluminum, magnesium and even stainless steel for many purposes.

The eccentric behavior of titanium can be explained rather simply It is actually an active chemical element, in

ILMENITE QUARRY of the National Lead Company in the Adiron-

a class with aluminum and magnesium. This accounts for the activity observed when the metal is hot or molten. When cooled and exposed to air, however, titanium acquires a thin, invisible coating of oxide and nitride which serves as an inert, impermeable chemical armor. Aluminum and magnesium are protected by passive coatings of the same type. Since these metals are purified by electrolysis and in commercial practice are never in the molten state, their natural chemical activity poses no problem. This indicates that any improved process which may be devised for purifying titanium will be electrolytic

E. I. du Pont de Nemours & Company, the first industrial organization to produce ductile titanium, sells the metal in sponge form for $5 a pound in 100-pound lots. Hundred-pound ingots cost $7 50 a pound. Even when mass production gets under way, probably in the early 1950s, the price is not expected to fall below $1 a pound for many years. Kroll process titanium will cost somewhere in the range of 60 cents to $1 25, when the metal reaches full commercial stature A standard stainless steel, with 18 per cent chromium and eight per cent nickel, sells for about 35 cents a pound, but on the other hand special steels bring as much as $3. Titanium's weight advantage is a vital factor in the price picture, for $1 titanium will be on a par with 60-cent steel. And the fact that titanium and iron go hand in hand in nature will make it economical to exploit low-grade ores to the advantage of both metals

Titanium today is in the position held by aluminum at the turn of the century Although metallurgists and engineers foresee a brilliant future for this new and exciting metal, they can no more foretell its ultimate applications than men 50 years ago could predict the use of aluminum in automobile motors and aircraft. It is reasonable to assume, however, that in this age of close-knit technology titanium will grow toward commercial maturity at a far more rapid pace than aluminum. The rate of development of the titanium industry, compared with that of the aluminum industry, probably will be proportional to the development of atomic energy compared with the sluggish early progress in electricity.

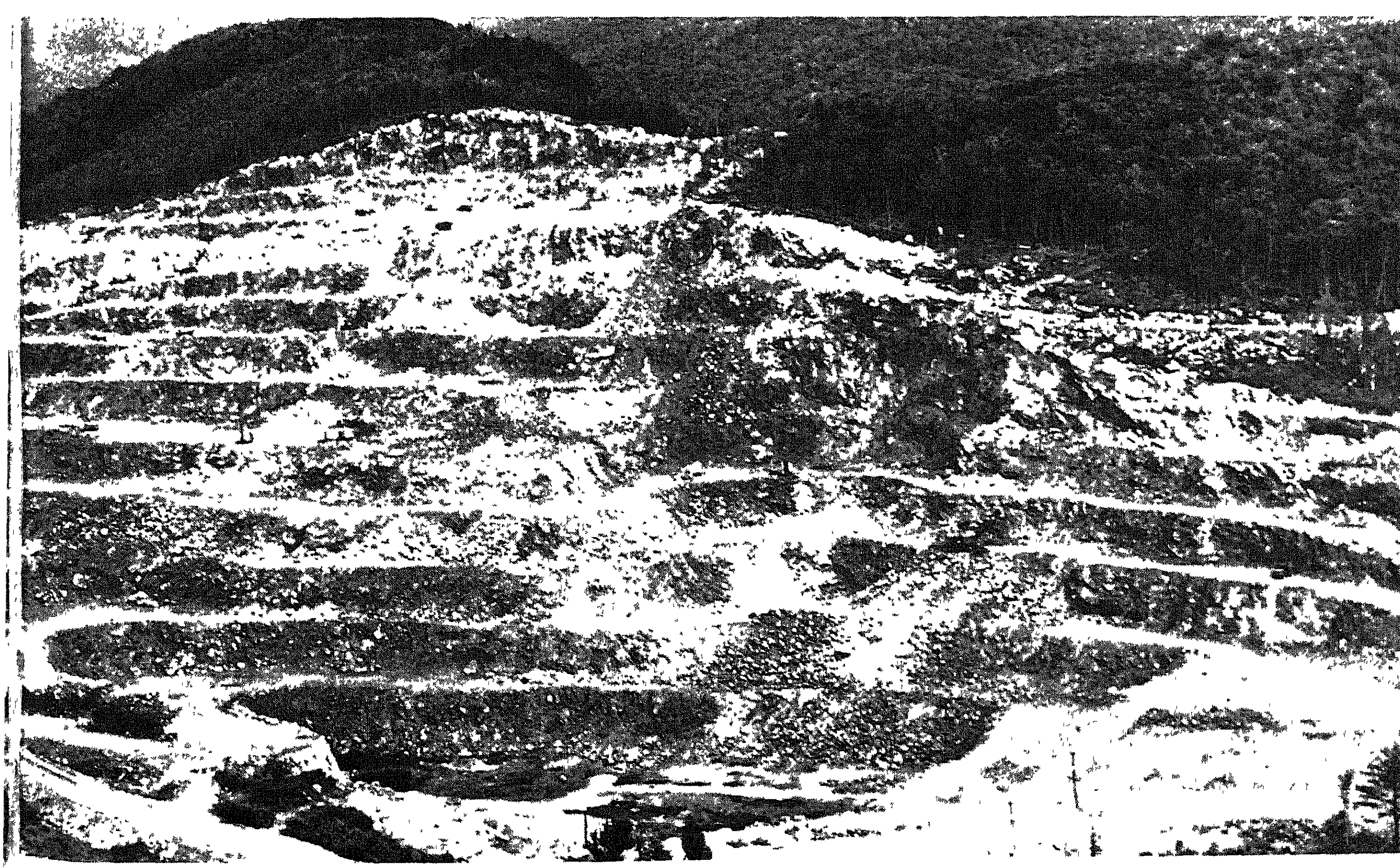
Titanium is only the first of several chemical elements scheduled to make their debuts as metals within the next few years. Another is zirconium, which is now ready for commercial development. It is heavier than titanium, but even more resistant to corrosion and high temperatures Boron, vanadium, and silicon, the latter the earth's most plentiful element, also show some promise as structural materials

All of the new metals have one thing in common abundance Their advent as useful metals represents something new in metallurgy Many resources of the convenient, easy-to-process metals, such as lead, tin, zinc and copper, are running low Faced with shortages that were brought to a head by the lavish wartime expenditure of materials, we are forced to turn to unfamiliar metals, which are fortunately plentiful.

Much of the development of titanium and the other new metallurgical candidates is due to the foresight of the U. S. Bureau of Mines In 1935 the Bureau's Metallurgical Division under Dr. Reginald S Dean embarked on a program with two objectives, to develop methods of processing low-grade ores, and to evaluate the worth of abundant but little-known metals This research has already accumulated dividends that we may be able to begin collecting in the near future.

Among the new metals titanium has now arrived, and others will swiftly follow in its footsteps. It is entirely possible that in years to come, this new race of metals will virtually dispossess all of today's common metals with the exception of aluminum, iron, and magnesium.

George Boehm is radio editor of the American Chemical Society.



dack Mountains is one of the chief present sources of titanium. The ore is plentiful in the U. S. Ilmenite also yields iron, which makes its mining doubly fruitful. This mine also produces the rich iron ore magnetite.

THE EVOLUTION OF SEX

Has it outlived its usefulness to the species Homo sapiens? A biologist speculates on the origin and significance of the two-sex system

by Paul A. Zahl

THE FIRST living things apparently were single-celled microbes that floated in Archeozoic seas more than a billion years ago. Their lives were sexless and relatively uncomplicated. In an age without males or females, reproduction took place simply by the splitting of the mother cell's protoplasm into two new organisms. So far as survival through the ages is concerned, this system was highly efficient. The descendants of those neuter creatures still exist today among such simple organisms as yeasts, bacteria and certain blue-green algae.

Sex did not appear on this planet until millions of years after life began. And the specialized two-sex system was a relatively late development. Along the way nature has experimented with a rich and bizarre variety of asexual, multisexual and male-female systems. Some starfish, for example, may reproduce by releasing an arm. There are certain moths in which maleness and femaleness may exist in a wide graduation of degrees. Many organisms, including snails, worms and some fish, are hermaphroditic, bearing both male and female organs. There are eels that start life with male organs which are later replaced by female ones. Among some worms birth is invariably fatal, the mothers nourishing their embryos until their bodies burst. Another worm reproduces simply by breaking into pieces. There is a marine organism, *Bonellia*, of which the female is about the size of a walnut, while the male is microscopic and lives inside the female's body. There is a species of *Paramecium* that has no fewer than eight different grades of sexuality. A riotous diversity similarly exists in the plant kingdom. The mangrove not only bears sexual flowers but sends out root arches which enable it to cover quickly vast areas of swampland. The wild strawberry sends forth runners which sprout at properly spaced intervals. Some tropical flora drop leaves which, upon striking the soil, grow roots and eventually turn into new plants. Some of the lower plants exhibit a sexuality describable only in various degrees of plusness and minusness.

Why did nature, in the higher animals, discard the straightforward system of nonsexual reproduction? In particular, what biological justification is there for the two-sex system, since there are ways of reproducing without it? The answer obviously must be sought in a study of the evolution of sexual from nonsexual forms.

The first great step toward sexuality almost certainly was the development in simple organisms of an organized nucleus in which heredity-bearing materials, that is, genes, were concentrated. This crucial innovation appears to have occurred somewhere in the taxonomic interval between primitive blue-green algae and bacteria on the one hand and nucleated green and brown algae on the other. Primitive—or better—archaic organisms showing complete nuclei are perhaps best typified today by *Chlamydomonas*, a unicellular green alga, or *Cryptomonas*, a unicellular relative of the brown algae.

AGES ago a cell floating somewhere in the still-warm seas, or secreted in some moist rock crevasse, underwent mutational changes in some of its genes, which resulted in conversion of its gene-bearing vitals into one or more spermlike creatures capable of swimming by means of whipping tails. Once liberated, a spermlike swimmer set out to explore the waters surrounding the colony in which its parent cell had originated. Finally it settled on a ledge or a grain of sand and, with tendrils disintegrating, multiplied until a new colony had been formed. No genetic material was added or subtracted during this reproductive process; it was wholly nonsexual. But it was a truly presexual innovation, and it prospered, presumably because it served as an effective method for the dispersal of colonies, allowing the species to spread over greater areas and into more favorable environments.

The actual beginning of sex came when, as the result of another series of genetic changes, something happened in the nucleus of one of the swimming microbes, and it was powerfully attracted to another produced by an alien colony. These two cells were the first to recognize themselves as different from each other. They came together and fused. The two-in-one organism resulting from this chromosomal marriage divided into other individuals which, after swimming about for a time, settled down to form new colonies. Why the first swimming creature did not unite with one of its immediate neighbors, but was driven to seek a mate from another colony, is unknown. But the event certainly represents the first biological instance of selective fusion, and of its momentous corollary, sexuality. That this actually occurred among the primitive inhabitants of the young planet is postulated on the presexual and sexual behavior of many algae that still exist today.

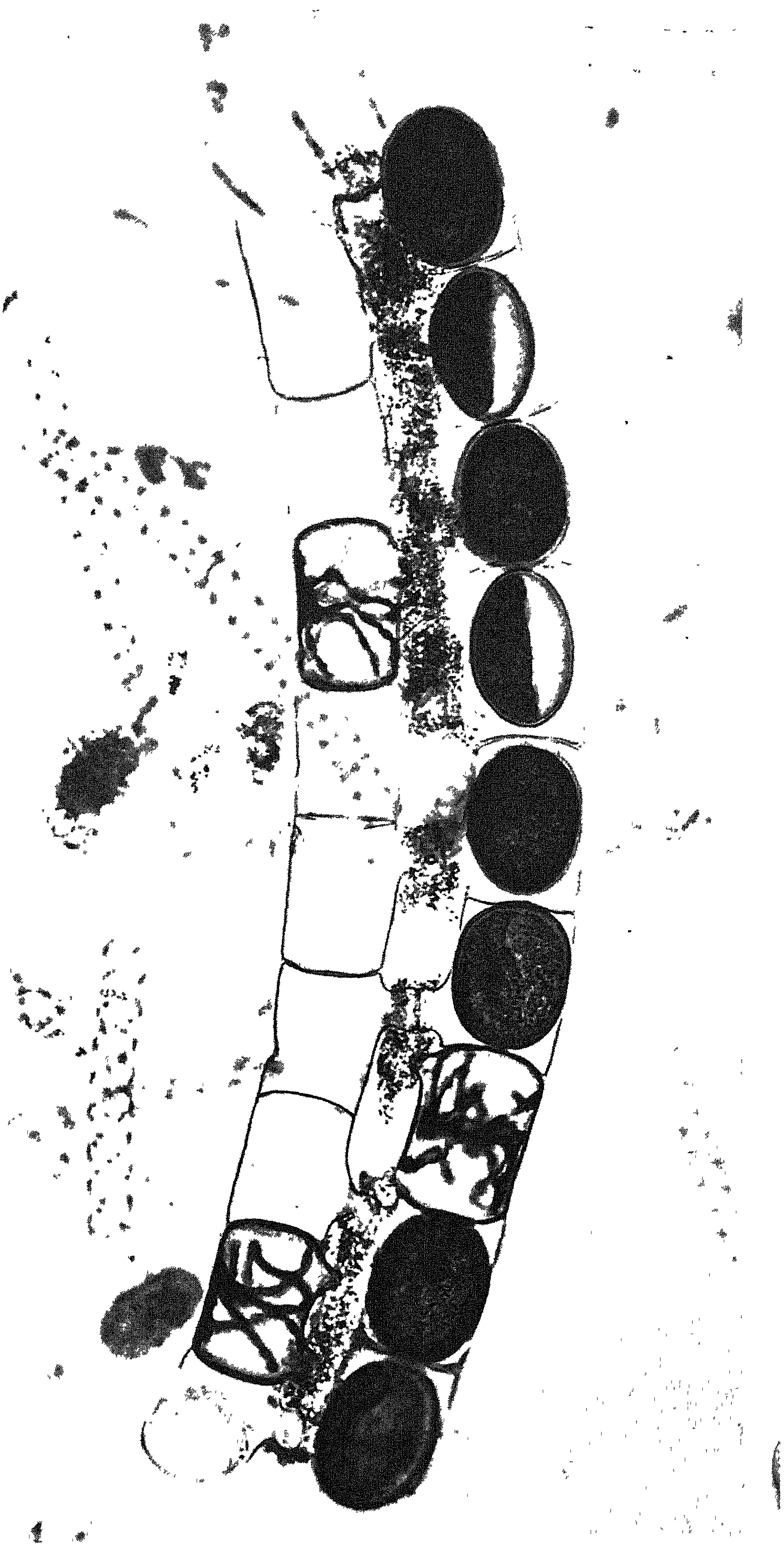
It should be noted that there were no structural differences among those earliest courting cells. They all looked alike; the difference between the "sexes" was simply chemical. But obvious external differences, as the final great step in sexual emergence, were soon to follow. Evidence for this is to be found in algae of the *Oedogonium* type (a genus of green fresh-water algae). The female cells became larger and less mobile than the male, and finally each type came to contain half of the species' characteristic number of chromosomes. Union of such cells resulted in re-establishment of the full chromosome number—a process found in all later sexual organisms. Throughout subsequent evolution, plants and the animals that evolved later came to produce large, relatively immobile, nutrient-filled female cells localized in special organs; small, free-swimming male cells were similarly housed until ready for release. These male and

female organisms laid the foundations for the sexual patterns of higher forms of life. The end of this evolutionary process was the adoption by the highest organisms of bisexuality as the sole method of reproduction.

THE traditional explanations of the male-female pattern are unconvincing. One of the earliest—and most easily disproved—is the anthropomorphic theory that the female of the species needs an unencumbered male companion to protect her and hunt her food during her pregnancy. Actually the fact is that the pregnant female animal generally is completely self-sufficient, and often has no further association with the male after breeding. Even in as highly developed an organism as man, the system of monogamy and care of the pregnant female by the male is comparatively recent, having sprung more from economo-cultural necessity than from fundamental biological urges.

Another theory is that sex is a rejuvenating device It rests mainly on observations of a phenomenon occurring in certain single-cell animals. Some paramecia, for example, multiply simply by pinching in two. But under adverse environmental conditions the organisms may become enfeebled, as indicated by their sluggish movements. At this point, a type of sexuality appears; one individual clings to another, and a partial exchange of chromosomal material occurs. Then the two individuals separate and—if fresh food is provided in the culture medium—begin to divide by the nonsexual method again. Immediately the old vigor returns, and succeeding generations appear to be hardy and refreshed. Although a kind of reinvigoration does seem to occur in a few instances and under special conditions, it is not a general phenomenon and cannot be considered a strong support for the theory The sexual episode in these organisms may be a means of rejuvenation, but did it originate as such?

The classical experiments of L. L. Woodruff at Yale University point to a negative answer. He found that if paramecia are grown continuously with ample supplies of fresh foods, no such joining-together occurs. More definite evidence is supplied by modern studies of cells in tissue culture. A tissue culture is made by isolating living cells and nurturing them in an incubator Each cell divides without becoming involved in any sexual process. A culture of chicken-heart cells at New York's Rockefeller Institute for Medical Research survived in excellent condition for over 30 years, having multiplied through thousands of nonsexual generations. Yet never once was there evidence of any aging or devitalization, so long as adequate nourishment was provided. Similarly, cancer cells transplanted from one



ORIGIN OF SEX probably occurred in algae. Shown here is fusion of cell material from two filaments of *Spirogyra*, an advanced variety of green alga. Other lines of sexuality may have evolved in the brown and the red algae.

mouse to another since the early 1900s have lived through many nonsexual divisions with no loss of vigor. Furthermore, bacteria and the most primitive present-day algae have persisted for more than a billion years, vigorous and essentially unchanged, by the sole use of the nonsexual method of reproduction.

MOST biologists today have rejected the old theories and concluded that sex developed as an evolutionary device for producing adaptive variety among living things. Nonsexual reproduction is an enemy of change. Suppose, for example, that the higher animals had only a single sex, and that every individual of a species had an identical reproductive system in which conception was initiated by a germinal cell that passed into an incubating uterus. Such a system is within the realm of physiological possibility, as evidenced by many experiments in which the ova of rabbits, frogs and other animals have been fertilized artificially by chemical means and have produced offspring without sperm or any male help. With a reproductive system of this kind, each offspring, except in rare cases, would be an exact duplicate of its parent.

Such genetic inflexibility obviously would have made evolution, on the scale that occurred, impossible. The development of sexuality in living organisms produced a method for the constant mixture and recombination of different genes from two parents, thus yielding offspring that could differ in greater or lesser degree from their parents. Sexual reproduction, therefore, enormously increased the differences among organisms, and continuously produced variations and new forms that could survive in the changing environment created by the vast geological upheavals and alterations of climate on the earth.

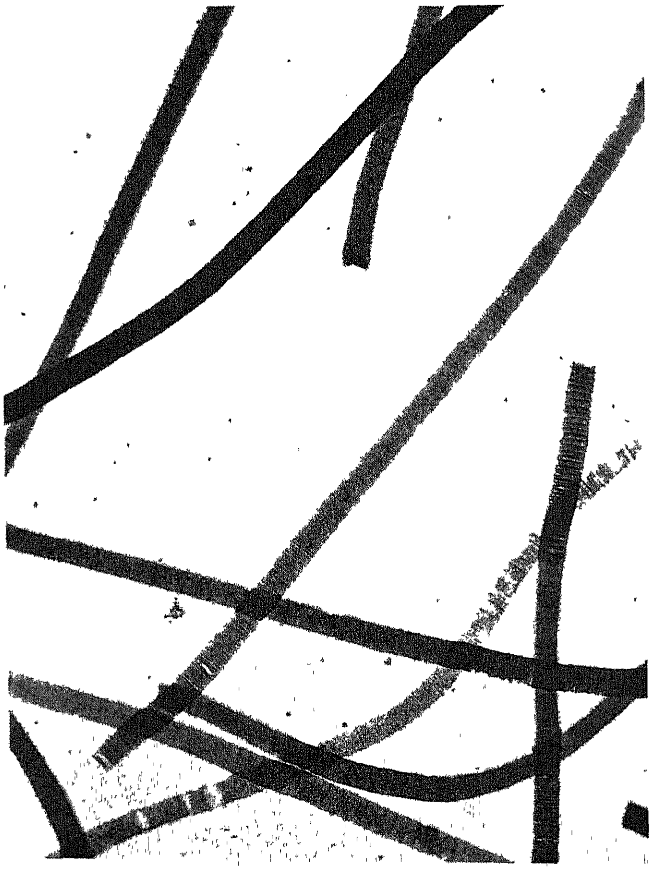
If the sexual system of reproduction was necessary for evolution, how may we explain the original evolution of the nonsexual Archeozoic algae into sexual forms?

The answer, of course, is mutation. A mutation does not spring from the mere mingling of chromosomes, but from fundamental changes in the chemical structure of a gene, changes that are transmitted from generation to generation. Such structural changes within genes may be produced by familiar physical or chemical forces. It is known that high-energy radiations from radioactive elements and cosmic rays, which have been bombarding the cells of the earth's inhabitants from the beginning of time, are capable of smashing into dividing chromosomes and producing disruptions that result in permanent mutations. Recent work indicates that many chemicals also may produce such effects, and that high temperature may increase the mutation rate. Finally, fragmentation of chromosomal particles during sexual maturation and a rearrangement of the relative position of these fragments may cause new characteristics to develop in the progeny

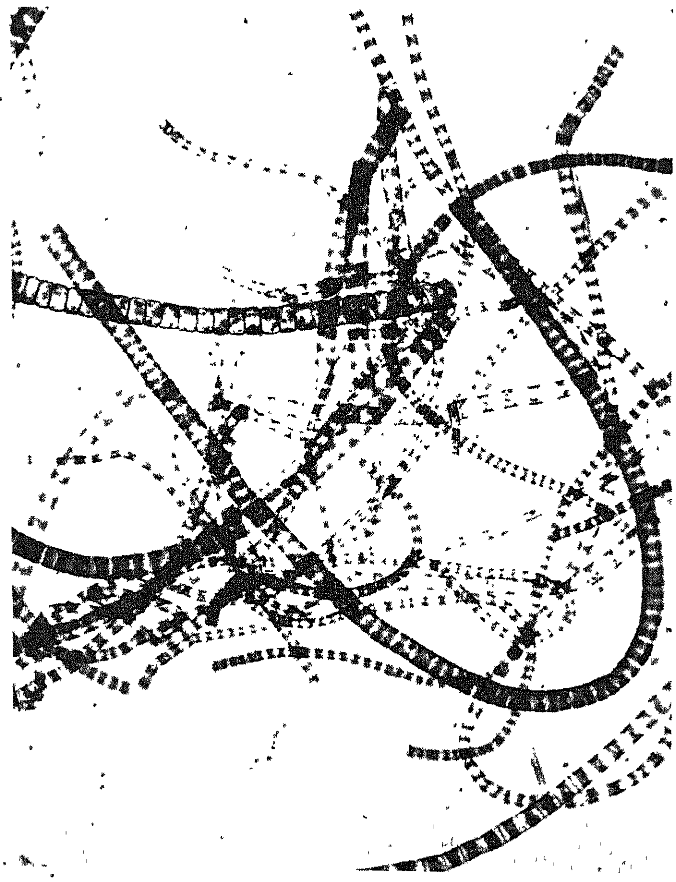
Mutations explain not only the original changes in the sexless organisms but the development of completely new species from sexual organisms Normally, of course, no offspring can possess characteristics not genetically latent in its parents, just as no matter how many times one throws a conventional pair of dice, no numbers but those from two to 12 can come up. But mutations may etch new numbers on the dice

IT MUST be pointed out that the mutations appear to be entirely random and undirected, only those which have a survival value will be passed on. For every successful mutation, there have been innumerable disadvantageous or lethal ones that led to the extinction of their bearers.

Thus, from both inference and experiment, modern biology has arrived at the following premises: 1) sex originated not specifically as a reproductive device but as the result of many fortuitous mutations; 2) sexuality made possible the intermingling of mutations and variations



FIRST STEP toward sexuality was the concentration of heredity-bearing genes in an organized nucleus, which began to develop in algae such as *Oscillatoria*, above.



NEXT STEP came as the result of mutations in more advanced algae, here represented by modern *Ulothrix*, which liberated spermlike swimmers from the cell.

in one family line with those of another, and thereby produced a far wider range of varying individuals within a given species than would have been possible if the species were limited to nonsexual reproduction, 3) wide variations within such sexually produced and mutating populations allowed maximum advantage in the struggle for existence. Thus the biological phenomenon of sex provided one of the keystones for the process of organic evolution

THESE findings suggest some speculations concerning the biological significance of sex in human beings. Man, like other sexually reproducing organisms, evolved by means of mutation, variation and selection He evolved, that is, so long as an effective selective process was operative. But that series of mutations which led him from a primate and subhuman existence to subjectivity and self-consciousness completely altered man's evolutionary course

Endowed now with unique intellectual powers and apparent free will, man found himself able to establish his own values for living. He built a framework of ethics, reinforced by a growing consideration for the integrity and rights of his brother human beings. In so doing, he tended to abandon the survival-of-the-fittest pattern, substituting precepts which demanded survival and reproduction of the "fit" and "unfit" alike. Human history appears to have been one long attempt to negate instincts that operate among the animals With this negation. some of the biological urges which motivated animals decreased in functional significance. This applies conspicuously to sexuality.

Indeed, in view of man's ethical and religious evolution during the last few millennia, one is at a loss to find a rational biological defense for the two-sex system in civilized human society. It is difficult to escape the conclusion that human sexuality persists as a relic of bygone days, when organic rather than psychological and social evolution was the keynote of all life.

It is only in societies where the "fittest" are selected to pass on their "fitting" germ plasm that reproduction by the sexual method has a biological justification Christianlike ethics tend to vitiate the mechanism of selective survival Man —so long as he clings to such ethics—may be broadly regarded as having ceased to evolve organically. He still continues to exhibit a normal distribution of variations, but by coddling germ plasm which in the natural competitive state would have been swept to extinction, he can no longer take evolutionary advantage of normally occurring mutations and variations. He may continue to evolve intellectually and socially, but his organic evolution via the sexual mechanism—again, within the ethical framework described—appears to have reached a self-limiting plateau

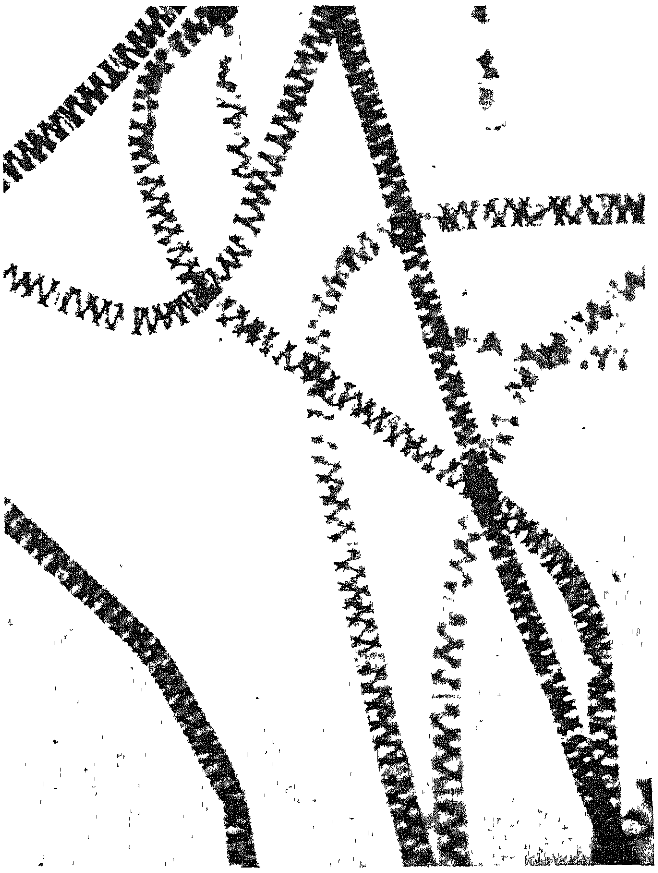
Is it possible, then, that man would suffer no real loss, aside from the pleasures and torments of the flesh, if he reverted to the condition of a nonsexually reproducing organism? And what would be the scheme of things, if such a physiological miracle came to pass?

The hedonistic elements of sex, which in all ages have helped inspire the arts and other phases of civilization, would probably be replaced by equally powerful motives Perhaps some would see a great advantage in freeing the human organism from a jungle-born urge which perennially has been a dominant and often psychotic force in the minds of men and women. A species of human beings which was freed of these motivations might conceivably be released to accept with less inhibition or encumbrance the challenge of the scientific, social and religious aspirations of mankind.

Is it possible that thoughts of this nature influenced the early religionists in their adoption of voluntary celibacy as an aid to inner enlightenment?

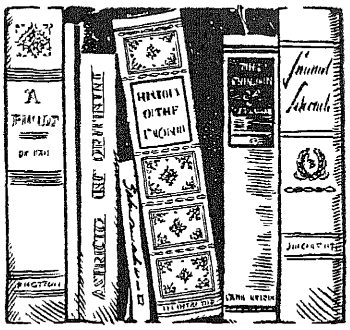
Paul A Zahl is associate director of the Haskins Laboratories in New York City.

MALE AND FEMALE cells of differing structure perhaps first appeared in algae of the *Oedogonium* type. The male cells are smaller and more active than female.



ADVANCED STAGE in early development of sexual fusion among algae is typified by *Spirogyra,* which shows union of cellular material of separate filaments.

ON MARCH 16, 1926 Dr. Goddard stood beside the launching frame of the first liquid-fuel rocket. The fuel of the rocket was gasoline oxidized by liquid oxygen. The rocket's motor is at the top; the fuel and oxygen tanks trail behind it. This arrangement was favored in early experiments because it provided greater stability.



BOOKS

The notes of Robert H. Goddard, the reticent pioneer of high-altitude rocket development

by Peter van Dresser

ROCKET DEVELOPMENT. Edited from the notes of Robert Hutchins Goddard by Esther C Goddard and G. Edward Pendray. Prentice-Hall, Incorporated ($6.50).

IN the unfolding drama of high technology now in progress, rocket propulsion, with its ultimate implications of extraterrestrial navigation, plays a romantic role second only to that of nuclear physics. The visions of a coming neo-Columbian era of exploration of the skies, with which the Jules Vernes and H. G. Wellses began to trouble the imagination of earthlings a generation ago, have become a concern of practical men. The first voyage to the moon is now a conceivable engineering potentiality; the construction of an artificial satellite to encircle the earth in a stable orbit is a project seriously suggested by the Secretary of Defense.

For most of the first half of this century Robert Hutchins Goddard, the reticent professor of physics at Clark University, occupied a unique position on this frontier. His scientific interest in the propulsion of jet-engines to very high altitudes was awakened several years before the first flying machine took the air. In 1907 he wrote and submitted for publication a paper on the utilization of radioactive energy for interplanetary jet propulsion. His preoccupation with the potentialities of rocket flight continued from the turn of the century until his death in 1945, and resulted in the publication of one of the first mathematical studies of the subject. His practical experimentation in the field led him to conceive and construct what is probably the first liquid-propellant rocket ever flown; the historic flight took place at Auburn, Mass., in 1926. His series of tests during the 1930s of increasingly large and complex machines, financed by the Daniel and Florence Guggenheim Foundation, formed the most elaborate and consistent program of such research until the German development of the V-rockets of the Second World War.

During all this period Dr. Goddard stood forth as a champion of the embryo technique of rocketry and astronautics—although he was a somewhat shadowy figure to the world at large, due to the scarcity of his publications, the inaccessibility of his experiments and his personal reticence. Despite the spectacular emergence of heavier-than-air flight from cloud-cuckoo land speculation to reality during this period, public skepticism of the rocketeers persisted, and Goddard's position was a courageous one for a scientist of academic standing to maintain. Nonetheless, as a result of his standing he was what may be called the only "official" proponent of rocket research in America, the only scientist whose investigations merited the serious consideration of bodies such as the Smithsonian Institution, of government and military officialdom, and of research foundations.

In view of these circumstances, the meagerness of Dr. Goddard's written work has long been a source of disappointment to those interested in the subject. Unfortunately, the publication of the present volume does not dispel this sense of disappointment.

For well over two decades a body of international technical literature dealing with the thermodynamics of rocket engines and the ballistics of rocket flight has been accumulating. *Wege zur Raumschiffahrt*, the original edition of which was published by the Rumanian physicist and experimenter Hermann Oberth in 1923, is the first and greatest classic of this literature. The broad comprehension that this book reveals of the problems involved remains today hardly challenged. *L'Astronautique*, published by the aviation engineer Robert Esnault-Pelterie in 1930, is another classic of this kind, framed with typically French precision and elegance. Dozens of other less comprehensive books and papers might be enumerated, dealing with both theoretical and practical aspects of the subject.

Dr. Goddard's own first contribution to this literature, *A Method of Reaching Extreme Altitudes*, published by the Smithsonian in 1919, did not indicate a talent moving with ease in the field of mathematically controlled speculation. This paper, although discussing what was then an extremely daring subject—a rocket-shot to the moon—confined itself to a strictly limited examination of the trajectory and mass relations of a smokeless-powder rocket. It reached the conclusion that 600 pounds of explosive would be necessary to project a one-pound mass to the velocity of escape from the earth. Goddard's exercise was notable for its Yankee literalness and pointedly realistic approach.

From such a talent it would be unreasonable to expect an elaborate contribution to the general theory of celestial ballistics. One would hope to find, however, as a result of a quarter century of effort, some major addition to the emerging technology of rocket engineering, enriched by the knowledge gained in a lifetime devoted to the field.

The present publication does not form such a document. Compiled by Mrs. Goddard and G. Edward Pendray from Dr. Goddard's notebooks covering several series of tests at Camp Devens. Mass. (1929-1930), Roswell, N. M. (1930-1932; 1934-1941), and Clark University (1932-1941), and with a preface by Harry Guggenheim, the volume presents a mass of minutiae regarding the particular arrangements and equipment employed. These details now can have only a historical—one might almost say an antiquarian—importance.

Published a decade or more ago, such data might have been of intense and seminal interest to experimenters; today they are nearly valueless. For it is a sad paradox that, however clearly Dr. Goddard anticipated many of the principles embodied in modern rocket technology, there is little evidence that his work formed a vital link in the evolution of that technology. German military rocketry evolved rather directly out of the activities of the European group which included Oberth, Esnault-Pelterie, Willy Ley, Walter Hohman, Max Valier, Johannes Winkler, Eugen Sanger, Franz von Hoeft and Rudolf Nebel. American rocketry—to the extent that it is not a transplantation—is built on the accumulated experience of several research groups which had only the most indirect contact with Dr. Goddard and his experiments until the latter years of the war. Mr. Guggenheim's prefatory depiction of Dr. Goddard as the "undisputed father of modern rocketry" can be justified only in the sense that he was a symbol of academic science's acknowledgement—however cautious and reserved—of the potentialities of the liquid-fuel rocket. The psychological value of such a contribution may indeed be great, but its evaluation is difficult.

To anyone familiar with the early work in rocket development, a reading of these notes must convey a strong impression of the hampering effect of isolation upon the scientific investigator. Time

and again a familiarity with the findings of other competent minds would have spelled the difference between success and qualified failure in Dr Goddard's experiments. Despite his remarkably complete concept of the anatomy of the liquid-fuel high-altitude rocket, gaps in his grasp of principles constantly thwarted efforts to construct and fly a really successful machine. These gaps might easily have been closed by knowledge already in existence

For example, his tests were plagued to the last by the limited endurance and liability to failure of his motors. The supreme importance of intensive integral-wall cooling of rocket chambers and nozzles by propellants under rapid forced circulation had been pointed out by several investigators. They had discussed at length the difficulty of developing any construction material that would stand up in an engine operating at temperatures of 5,000 to 6,000 degrees F Oberth went so far as to recommend silver walls for such combustion chambers, and Eugen Sanger, a Viennese aeronautical engineer, published a strikingly prophetic analysis of the heat-flow relationships in the rocket motor and the necessary construction specifications and design parameters of its cooling system He pointed out that such a system must be calculated to absorb energy of the order of one horsepower per square centimeter at every point on the interior surface of the combustion chamber and nozzle. Yet Dr. Goddard consistently thought of motor cooling as a sort of auxiliary device He applied copper or aluminum coolant tubes externally to his motors, but they were never formed integrally into the chamber walls, and were usually referred to in his notes as fuel or nitrogen vaporizers. The real focus of his interest, as indicated by his notes and by his numerous patents, lay in the exact positioning and shaping of propellant inlet ports, and he conducted scores of tests centered on this relatively unimportant point.

Similarly, the Goddard motors were invariably equipped with long De Laval type nozzles with excessive expansion ratios, although it had early been shown that such nozzles were detrimental to the efficient operation of a rocket motor discharging into the atmosphere.

Again, Dr. Goddard seemed unable to evolve a clear-cut technique for proving-stand static tests for the various elements in motors and propellant-feed systems, although such techniques were adopted by all experimenters as soon as they began to grapple with the manifold problems of rocket development. His tests were usually conducted with complete rockets. There were so many interacting factors to consider—combustion-chamber shape and size, rate of nitrogen and oxygen feed and vaporization, performance of gas generators, turbines and pumps, the coordination of complex electrical and mechanical control devices—that the specific causes of failure in his rockets were usually difficult to determine precisely. When to these complications were added those arising in the course of flight tests, the task of evaluating results became virtually dependent on intuition.

Such deficiencies prevented Dr. Goddard from achieving a single impressive altitude flight capable of convincing the layman of the unique capabilities of the liquid-propellant rocket, they also prevented him from developing a reaction motor which by consistent, efficient and duplicable test-block performance might have impressed engineers

The dispersion of efforts of a man pressed for time, sure of the validity of his own superabundant ideas and eager for tangible results, may be the explanation of these characteristics of Dr. Goddard's experimental career Yet the secrecy which surrounded his work, and the intellectual isolation in which it appears to have been conducted, produced unhappy results Whatever the cause of this secrecy—whether supersensitivity to general skepticism, official and academic conservatism, or an awareness of military implications—it served only to increase rather than dispel whatever aura of the fantastic surrounded rocket experimentation It served also to discourage the growth of an informed technical public in this field in the U S And it certainly did not prevent Nazi engineers—building directly upon the thinking of previous independent researchers, few of whom were encouraged by officialdom—from developing a rocket technology under the exigencies of wartime far in advance of anything achieved elsewhere in the world.

Goddard's career and his frustrations may perhaps suggest food for thought in connection with the present trend toward controlled, officially sponsored and censored research.

Peter van Dresser is a city planner, an author of articles about rockets and a charter member of the American Rocket Society

JANE'S FIGHTING SHIPS, 1947-48 The Macmillan Company ($20.00) The 50th issue of one of the few publications connected with the art of war that even a peace-loving man might enjoy. For its anniversary, the famous fat, royal blue, oblong volume is stuffed with some new and many dependable old features, ably edited by the late Francis E. McMurtrie In addition to thousands of photographs (the first issue in 1898 had pen and ink drawings) and descriptions, including some of Russia's submarine fleet, there is an index of the major warships of the world, 1897-1947, an immense array of silhouettes of the world's "ironclads," 1860-1945, an article on the biggest warships ever built, the Japanese *Yamato* and *Musashi* (both destroyed by U S. bomb and torpedo attacks), a summary of German, Japanese and Italian war losses, a foreword on future naval plans of the major powers, with a warning that the Japanese Navy, reconstituted by us, is about to arise like the Phoenix from its ashes—thus repeating, perhaps, the renaissance, after the Treaty of Versailles, of the German Fleet, and a reminiscent essay about Fred T. Jane by McMurtrie. This amazing Britisher who died in 1916 was the son of a vicar, a successful Rugby three-quarter at Exeter, a lover of everything that floats, the author of numerous books (such as *The Incubated Girl, To Venus in Five Seconds, The Violet Flame*), the conductor of a column entitled *Garage Yarns*, a candidate for Parliament on an independent "Navy before Party" ticket, a formidable practical joker who once actually kidnapped an M P to prevent him from addressing a meeting and planned "a similar hoax" at the expense of Winston Churchill and, finally, the founder of this admirable series. Both an indispensable work for professionals and a fine book for occasional reading in every room of the house

MATHEMATICS FOR THE GENERAL READER, by E. C. Titchmarsh. Hutchinson's University Library, London ($1.75) Professor Titchmarsh, who holds the famous Savilian chair of geometry at Oxford, has written for the Hutchinson University Library series the ablest brief popularization of mathematics since A. N Whitehead's classic *Introduction to Mathematics*. In a small volume of 160 pages he provides adults who are willing to take thought to the subject—more than, say, 15 minutes a day—with a lucid, unhurried account of the science of number from arithmetic through algebra, trigonometry and the calculus. The style is easy; the examples, having been devised by a first-class mathematician, are fresh and unusually helpful; the text is guided by a subtle understanding of the difficulties of the average educated grownup who rarely manages to throw off the trauma of his first school encounter with fractions An excellent little book.

THE NAMING OF THE TELESCOPE, by Edward Rosen. Henry Schuman ($2.50). Who named the telescope? Was it Frederick Cesi? Was it John Demisiani? Who were the Lynxes? Was John Baptist della Porta a liar? Who attended the famous banquet in Galileo's honor at Monsignor Malvasia's estate outside the St. Pancratius gate? The answers, or at least some plausible answers, to these major questions may be found in Dr. Rosen's small monograph. An almost incredible example of academic petit point, yet both ingenious and charming.

Harlow Shapley provides a foreword, and there are a number of plates and illustrations.

THE CHEMISTRY OF PENICILLIN. Princeton University Press ($36.00). A monumental report of studies by joint British and American research teams to ascertain the chemistry of penicillin and to devise methods for its synthesis. The monograph is a prototype of collaboration among men, regardless of nationality, in a field far more valuable than that of nuclear physics—judging by the results to date. Though discovered by Alexander Fleming in London in 1928, this incomparable servant from the plant world was not brought into commercial production until 1941, after prolonged research stimulated by the needs of the war. Throughout the war years further intensive inquiries were conducted under the joint sponsorship of the Office of Scientific Research and Development and the Medical Research Council in London. By using the "synthetic ability of the mold," it became possible to reproduce on a large scale what the English chemist John Read has described as "this masterpiece of natural planning in the world of molecular architecture." As nearly everyone knows, penicillin was brilliantly successful in the fight against the bacteria causing sepsis in wounds and against the organisms responsible for many serious diseases, including pneumonia, meningitis, anthrax, gonorrhea and syphilis. Once the organic chemist succeeds in a pure synthesis of the basic molecule (at least four varieties of penicillin are known to exist), modifications of the natural substance may be undertaken to enlarge the range of its antibiotic effectiveness. This admirable volume does honor to the editors, the contributors and the publisher.

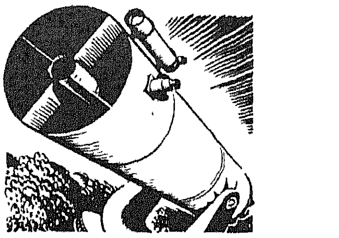
THE ALPHABET, by David Diringer. Philosophical Library ($12.50). A remarkably erudite history of writing from cuneiform and hieroglyphic scripts through the Greek alphabet and its 50 descendants. Dr. Diringer's extraordinary explorations in this labyrinth have led him to the conclusion that our own alphabet, with its 26 signs, is a legacy from the Etruscans who, in turn, were influenced by the Greeks, the Phoenicians and the Hebrews. The book is based upon the author's Italian work, *L'Alfabeto Nella Storia Della Civiltà* which appeared about a decade ago and here appears in English form "increased and recast." Anyone interested in science who is growing a little weary of the wonders of the atom can expect to find in the newer developments of the study of writing, as in the origins of language and gesture, fields as rich, as astonishing and as provocative as the regions unfolded by the popularizers of modern physics and astronomy. Diringer's learned monograph, it is true, makes few concessions to the general reader, but the subject will repay some effort. The hundreds of fascinating illustrations lighten the burden of the text.

AN INTRODUCTION TO COMPARATIVE BIOCHEMISTRY, by Ernest Baldwin. Cambridge University Press ($1.75). A third edition of a brief, well-written introduction to an investigation which aims, through attaining a clearer understanding of the chemistry of even such simple organisms as the starfish or earthworm, to get closer to the basic processes of life in all its organic manifestations. Though biochemistry is hardly out of its cradle, it has developed a great body of invaluable information on the subject of the "molecular events" associated with physiological behavior, and promises to contribute significantly to the study of growth, evolution and heredity

THE MATHEMATICAL BASIS OF THE ARTS, by Joseph Schillinger. Philosophical Library ($12.50). This frighteningly large, heavy and expensive book by the late Joseph Schillinger, a well-known teacher of musical composition, is devoted to proving that the forms of all the creative arts lend themselves to a precise, bloodless mathematical analysis and that "there is no reason why music or painting or poetry cannot be designed and executed just as engines or bridges are" The demonstration is neither original, clear, profound nor successful; it is also unendurably dull Some years ago when the artist and art critic Jay Hambidge expounded his theory of "dynamic symmetry" it was discovered that the warrant earmarks of great art occurring in painting and sculpture were also to be found in such objects as pots and pans. This, it would seem, points to at least one of the hazards of constructing *objets d'art* with mathematics: a person bent on producing the *Mona Lisa* by mathematical formula might find himself at the end with a pressure cooker.

BASIC PRINCIPLES OF PSYCHOANALYSIS, by A. A. Brill. Doubleday and Company ($3.45). Dr. Brill, famous for his translations of Freud and as a pioneer in introducing the theories of psychoanalysis in the U. S., completed this revised version of an earlier work just before his death last year. It is easily understood and made thoroughly readable by its many case histories and examples clearly presented in Dr. Brill's entertaining though occasionally dogmatic manner. Brill was less inclined to stray from the fundamental teachings of the master than the master himself, and thus it comes about that many of his views seem dated in a discipline which has evolved and is still evolving so rapidly that the various neuroses, psychoses and other neural disturbances have a hard time keeping pace with the theory.

J. R. N.



THE AMATEU

Conducted by Albert G. Ingalls

ON FEBRUARY 22 Russell Williams Porter, patron saint of amateur telescope makers, died of a heart attack at his home in Pasadena, Calif. He was 77. Several years previously Porter had jotted on a scrap of paper, "My dream is to pass out realizing that I had just licked some beautiful problem in applied optics." When he died he had just completed the drawings of an immense spectrograph for the 200-inch telescope.

Porter's long life was crowded with work and fun. And to him most of the work was fun. He enjoyed the uncommon satisfaction of being able to do the things he had dreamed of doing. A year ago he was asked what he might have done if he had inherited a fortune. He answered, "Just what I've been doing." Porter was a serene and unhurried man whom few things ruffled. Among all those who knew him there were few who would not gladly have exchanged their lives and personalities for his.

Porter was born on December 13, 1871, in the front bedroom of a venerable homestead in Springfield, Vt. He was the fifth and last child of Frederick and Caroline Porter. His mother was then 51, one unusual fact of Porter's unusual life. Frederick Porter, who had been born in the same room, manufactured 75,000 baby carriages a year and prospered. He was also an inventor. Parts for baby carriages remain today in the old barn beside the Porter homestead.

Porter's boyhood friends, who said that he was lazy and showed little promise, called him "Pussy." He spent more than a year at both Norwich University and the University of Vermont. Then he wanted to enter the Massachusetts Institute of Technology to study architecture, for he was already skillful with pencil and brush. His father, however, was no longer prosperous. Porter borrowed $1,000 to enter the Institute in 1894.

That year Porter heard Robert E. Peary lecture on the Arctic, an event that cost him a dozen years of his career. From this moment he burned with a passion for exploration and adventure. Peary half agreed to take him North but Porter's elderly mother secretly asked the explorer to reject him, and this Peary did without revealing the secret.

Porter's interest in the Arctic was not diminished. Soon he met the affable and plausible Dr. Frederick A. Cook, another man who had designs on the North Pole. In the summer of 1894 he went with a large party to Greenland in Cook's antiquated vessel. The ship tore out her iron bottom on Greenland's rocks, and a hundred shivering men returned home packed on top of the codfish in a fishing schooner. Cook's *Last Cruise of the Miranda* tells the unhappy story.

Porter did go to the North with Peary in the summer of 1896. There was no hardship, a summer trip to Greenland being no worse than a January thaw in Maine. Yet the trip was a beginning, and the following summer the 26-year-old Porter herded a party of M.I.T. students to Frobisher Bay in Baffin Land at $300 a head. The trip was made on Peary's vessel, which debarked the voyagers, continued to the North, and returned in the fall to pick them up again. Thus Porter paid off all his college indebtedness. In Baffin Land he found Silurian fossils, which he presented to the paleontologists of the American Museum of Natural History in an old sock. One of the fossils bears the name *Orthoceras porteri*. Forty years later Porter wrote, "Stefansson told me my report on Frobisher Bay had been invaluable during World War II."

In the summer of 1898 Porter led a three-man party into upper British Columbia. Ostensibly the expedition was to do ethnological research for the American Museum, but the real objective was to find an overland route to the gold in the Klondike. Defeated, the party was forced to turn back at latitude 56. The next summer Porter gathered another paying party of college men and took them on Peary's ship to northwestern Greenland. In this way he was able to support himself until he had finished college.

In 1901 William Ziegler, a rich manufacturer, backed an expedition to find the Pole under a leader who proved to be such a tyrant that the expedition failed. Under a new leader in the following year, a second Ziegler expedition sailed to Franz Josef Land north of Russia. Its men landed 10 degrees from the Pole. Soon their base ship, an old whaler, was crushed in the ice and sank in the Arctic darkness. The expedition was cut off for a year and a half. Even then its men made attempts to reach the Pole. The story of this long adventure has been told by Anthony Fiala in *Fighting the Polar Ice*, published in 1907 and now out of print.

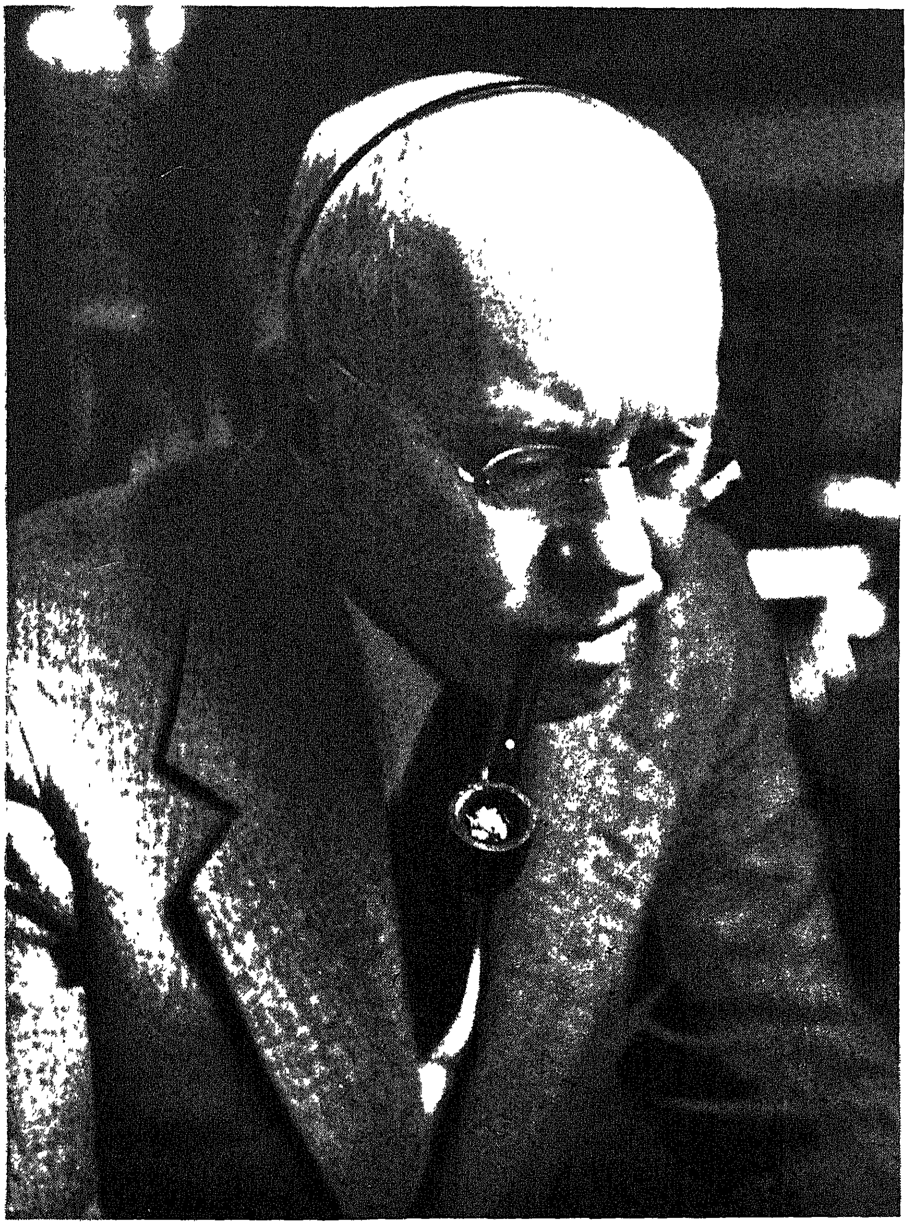
TO THE same volume Porter contributed a lively account of his escape from a camp 160 miles from the

ASTRONOMER

main party. There he had lived for 100 days on half rations which were finally exhausted. With another man and dogs he set out in midwinter, and after many trials—skis lost, sledge lost, death often near—he reached the main party and food. The following from Porter's narrative recounts an attack by polar bears

"Perhaps the bears took us for some animals good to eat. Surely we looked more like beasts than men in our bear-skins, and with our long hair and grease-covered faces. At sight of these bears the savage man rose dominant within me, and in my hair and down my spine ran an indescribable prickling sensation, and I knew why the hair on the wolf's back bristles when he hunts." At another stop: "We lay there shivering all day. The worst had come. Stormbound and no fuel 'Duncan,' I chattered, 'if I ever get out of this scrape alive, I'll make a beeline for the tropics and not go 10 degrees north or south of the equator for the rest of my days.'" Porter's unpublished diary makes even better reading than this, and shows remarkable literary gifts.

Porter forgot his oath about the tropics and headed north as a topographer with Dr. Cook in the next year. On this expedition Cook sent Porter and the others on a side trip, when they returned he claimed that he had climbed



RUSSELL PORTER, who died on February 22, was the patron saint of amateur astronomers. Although he always considered himself an amateur, his talents were of great service to the professionals. His famous pencil sketches were an important element in the building of the 200-inch telescope. Many of his ideas are now part of the completed instrument on Palomar Mountain.

Mount McKinley single-handed. His claims were later discredited. Porter was forced to attach Cook's luggage to recover his summer's earnings. "My hero's feet were made of clay," he commented years later.

On all these expeditions Porter acted as an astronomer, surveyor, meteorologist and artist. Sometimes he painted with water colors when the water had to be kept liquid over an alcohol lamp. Later in life he felt that the entire Arctic was hardly worth the misery it had cost mankind. The hardships described by later generations of explorers, who traveled with radio and other conveniences, did not impress Porter. It seemed to him almost wanton that planes quickly reached the places painfully attained by the earlier explorers on foot.

Fifteen years ago Porter summed up his exploring experiences in *Arctic Fever*, a 30,000-word manuscript copiously illustrated with his facile drawings. It remains unpublished, largely for economic reasons.

Porter was 36 when his Arctic fever was finally cured. In 1907 he met Alice Belle Marshall, the young postmistress of Port Clyde, Me. They were married and lived in a big farmhouse on "Land's End," a 50-acre peninsula near Port Clyde. There Porter built and sold cottage after cottage by the shore.

It was while living at Port Clyde that an article in *Popular Astronomy* caused Porter to make a 10-inch reflecting telescope (just as an article in *Popular Astronomy* later caused this magazine to discover Porter and to establish the hobby of amateur telescope making). Years later he jotted, "I shudder when I recall its horrible figure" Focograms of that mirror may be found in *The Astrophysical Journal* for June, 1918. Today's beginners will do well if they equal it.

From 1915 to 1917 Porter was an instructor in architecture at M.I.T Then he worked in optics at the National Bureau of Standards. In 1920 he returned to his native Springfield to work with his old friend James Hartness, head of the Jones and Lamson Machine Company. His specific duty was to develop the Hartness screw-thread comparator. Porter compressed this instrument with mirrors to save floor space He also adapted it to profiling needle eyes, saw teeth and dozens of other products. Another "duty" was to do whatever interested him most. Hartness knew how to get the most out of a genius. Case-hardened old machinists at J. and L. remarked, "Why, Porter took right hold of our machine tools without any apprenticeship." During his life he took hold of many things thus.

PORTER had not been in Springfield long before he gathered 16 mechanics from the town's industries and taught them to make reflecting telescopes. This he began on August 17, 1920. On December 7, 1923, he organized the Telescope Makers of Springfield.

One pleasant duty that Porter discovered at Jones and Lamson was to make nearly 100 ornamental "garden" telescopes with 6-inch $f/4$ mirrors. These his employer sold to the carriage trade at $400 each. The mirrors were figured by Porter's 18-year-old pupil Wilbur Perry, since then Chief Technician of the Ruling Engine Laboratory at the Johns Hopkins University.

Porter's quarter-century of relations with the readers of this magazine began in 1925 I still have the letters in which he guided my early efforts at telescope making. The pitch was too soft, boil it The pinhole was smaller than necessary. "And now get busy grinding."

One day early in 1928 George Ellery Hale mentioned to me over a New York luncheon table the possibility of building a large telescope, and listened to a description of the genius in Vermont who might help build it. Would he consent to see this genius?

A hasty telegram put Porter on the night train to New York and the next noon Hale and Porter and I lunched at the same table. I watched Porter's charm, knowledge and versatility go to work. From his facile fingers to the back of a menu fell those little sketches that came so effortlessly—his own ideas for big telescopes. After three hours Dr. Hale pocketed the menu and withdrew. Porter returned to Vermont and all summer pondered the mystery that seemed to be in the air. Autumn came and Hale sent J. A. Anderson and F. G. Pease to see Hartness, and to borrow Porter. Thus on November 26, 1928, Porter was able to write from the Twentieth Century Limited, on its way to Chicago, "The Porter family is headed for California." Months later Hale was to comment, "The most versatile man I have ever known."

What Porter did at Pasadena during his remaining two decades has been the subject of surmise, some of it incorrect. He was only embarrassed by those who, because they loved him, insisted that he had designed the 200-inch telescope and built it. No one man did either The basic design was executed by engineers, and Porter last summer remarked with vehemence, "I am not an engineer"

Largely it came down to this. At each of the many stages in the long evolution of the design, reached after interminable group discussions, Porter would convert the blueprints of the variations chosen for study into three-dimensional pencil drawings, each the equivalent, to those who studied them, of an actual working model (sometimes he went to the shops and built models—he always yearned to get his hands on tools)

There is no way to ascertain how many mistakes would have been embodied in the 200-inch telescope had there been no Porter, a consummate

artist who also understood the workings of what he was drawing. His work provided a close control on the telescope's development throughout.

When war came and the telescope was put in moth balls, Porter did exactly the same thing for defense. "My work," he wrote, "is mostly pencil sketches of gadgets that are hard to photograph. That's where I've got it over the man with the camera. I can cut an instrument all up, show its insides, yet not destroy it." His drawings went to Washington, and elsewhere in Navy circles.

When the war was over he wrote, "I can look back with satisfaction over the high-pressure jobs of the past few years—drawings of rockets, fuses, launchers, the Jap paper balloon, atomic bomb, proving ground work at Inyokern, Goldstone, Pendleton, NDRC and M.I.T. projects. At Washington they call me 'the cut-away man.'" But Washington sometimes drove Porter too hard, so that the man of 74 who had suffered a coronary thrombosis at 64 was in bed again for weeks. Military men had stood over him waving deadlines and he had worked day and night. Yet after one such illness his old sense of humor prevailed. He wrote, "Was blessed with three good-looking nurses, but only the head nurse would let me hold her hand."

PORTER did innumerable jobs besides the one described. In 1932 he disappeared for months, living alone in a little tent on Palomar Mountain, making a contour map of the whole broad plateau and laying out the future building sites and roads. The theodolite he used was the same one he had had in the Arctic. Then he returned to Pasadena and made a land model of Palomar, now under glass at the California Institute of Technology. He was the architect for the dome of the 200-inch telescope and for the other domes. I lived in Porter's home five weeks last summer, yet I still learn occasionally of jobs he did and never mentioned. He had a hand in practically everything.

In 1944 he wrote, "I often wonder how privileged I am out here, at my age. Whenever I want something I go to the optical or machine shop and find everything at my disposal. If I get into a jam for a gadget there's always someone to say, 'Let me do it for you.'"

"He is such a nice fellow to have around," was the tribute his immediate boss, Dr. Anderson, wrote of him. At various times in 1945 Porter wrote, "I'm now enjoying life hugely. The sky seems bluer, the trees greener, and every prospect pleases." Or, "I made $50 in bed today, just pushing my pencil." (Outside work came to him and he did much of it in bed.) Or, "All I care for is comfort, pipe tobacco, and good fellowship."

Few knew about Porter's major interest in music, fewer still that he composed music as an amateur hobby. While living in Vermont he had read books on harmony and counterpoint, then composed and orchestrated a symphonic movement. When he heard it played by an orchestra he sensed "how amateurish it really was," but he kept on composing because it was fun.

"Beethoven towers over them all," he wrote in 1938. "Next choices, to me, are Rimski-Korsakov, Tchaikovsky, Brahms, Mozart. If you could see my bedroom you'd see what I think of Beethoven. His nine symphonies, all the quartets and sonatas are within reach from my bed and I get almost as much fun from reading them as hearing them, in fact I do 'hear' them. Yes, they haunt you, as you say, long after the record has stopped (I had purchased a phonograph). What do you suppose is going on among the atoms in your brain to produce this?"

"On one side of my bed," he continued, "is a five-octave dinky piano cluttered with the scores I work on. Then, after I've labored for weeks, I get a hunch my theme is only a holdover from something I've heard before"

The little piano actually overhung his bed on one side, which made it difficult to arrange the bedclothes. I have seen him crawl into bed wearing all his clothes except his hat. In recent years Porter spent 16 hours a day in bed to conserve his strength. At night he often woke up to whack out his pipe on a big stone Eskimo lamp, light up, and work on musical scores or read or write.

In 1939 he wrote, "When I go East I'll head straight for you and your phonograph—to Hell with glass grinding." For seclusion the phonograph and 42 albums of Beethoven's chamber music and sonatas were lugged to the cellar shop, two steamer chairs were placed beside the phonograph and for a total of 23 hours during three days Beethoven disks were fed in as Porter, who was hard of hearing, controlled the volume and pitch. His favorite was the andante of Opus 97, the Archduke trio. In 1946 he again wrote, "Let's have another cellar orgy—play every one of Beet's again."

IN 1947 he jotted, "I'm growing old. Feel it in my bones." When I saw him in 1948 he had shrunk until his clothes hung pathetically loose. Though the work he still found to do fatigued him, he kept at it. When he wrote, "If I'm the patron saint, you're my Boswell," he knew he had not far to go but he made no complaint.

By Porter's own repeated request he was cremated and his ashes will be buried at his former home of Port Clyde. He will also have another monument. Through the efforts of the amateur astronomer David P. Barcroft, of Madera, Calif., a feature of the moon has been named after him. The lunar crater called Clavius B has been renamed Russell W. Porter by the British Astronomical Association.

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TITANIUM. Bruce W. Gonser in *Journal of Metals*, Section I, pages 6-9, January, 1949.

THE EVOLUTION OF SEX

THE STRUCTURE AND REPRODUCTION OF THE ALGAE, VOLUME I. F. E. Fritsch. Cambridge University Press, 1935.

SCIENTIFIC AMERICAN

PLANT HORMONES

FIFTY CENTS

May 1949

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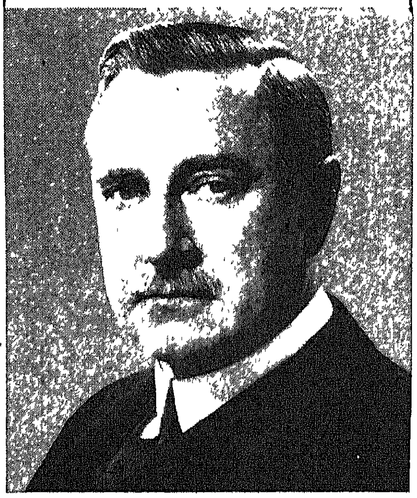

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"**The C.I.O.** has endorsed every effort to encourage the worker to put more of his earnings into U. S. Savings Bonds. They represent both security and independence."

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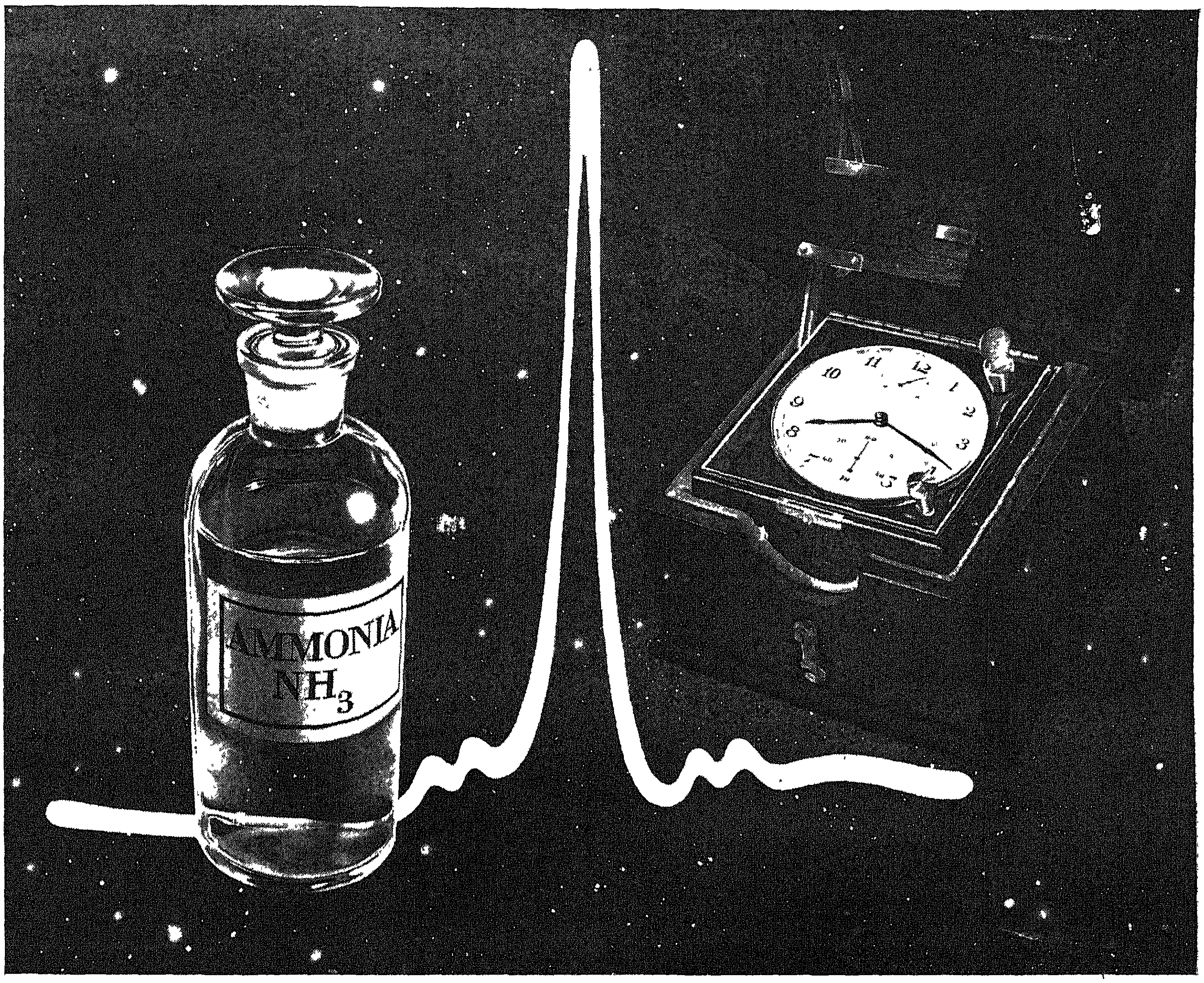

Using ammonia and radio waves, RCA scientists have devised a clock more accurate than the stars.

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LETTERS

Sirs:

I have read with interest the article on cosmic rays by George W. Gray in your March issue. The subject matter has been extremely well handled, and I feel it gives a very accurate and easily comprehended picture of the problem of cosmic-ray research. It will continue to be a reference for some time which we can assign to beginning students and to the general public who wish some material which will give them a general picture of what we are doing in cosmic-ray research.

Your presentation of the comments by Professor Blackett and Professor Ridenour in the same issue is also of interest. Professor Blackett, as you know, was awarded the Nobel prize for his work in cosmic rays. The work of several of his students is mentioned by Mr. Gray but I believe Professor Blackett is not mentioned in the cosmic-ray article. I cannot agree with Professor Ridenour's comment that Professor Blackett's book expresses views "so clearly the results of bias" that the "excesses and absurdities" make "the whole work" suspect. There have been other criticisms of Professor Blackett's book in the *Journal of the Atomic Scientists* which have disagreed with it, but at the same time have appreciated that this report of Blackett's has raised some real questions that should be carefully studied.

ROBERT B. BRODE

Department of Physics
University of California
Berkeley, Calif.

Sirs

In his rebuttal to P. M. S. Blackett, Louis Ridenour writes: "On Blackett's assumption that we dropped the bombs to prevent the Russian grab in Manchuria (he does not call it that), how did we succeed? . . . Consider also how we held back at Berlin and Prague until the Russians got there, in accordance with our agreements that their troops could enter these cities first."

General Dwight D. Eisenhower does not agree with this latter statement. A digest of his *Crusade in Europe* that appeared in *Life* says: "A natural objective beyond the Ruhr was Berlin . . . I decided, however, that it was not the logical or the most desirable objective for the forces of the Western Allies."

BERNICE KREISWIRTH

New York, N. Y.

Sirs:

I should like to make a few comments about Erich Fromm's "The Oedipus Myth" which appeared in your January issue. I read the article with astonishment at the author's method. In the year 1949 one who would attack Freud's concept of the Oedipus complex has vast and rich materials with which to grapple: not merely Freud's writings but the clinical observations of several generations of psychoanalysts throughout the world. Instead Fromm devotes most of his article to a discussion of Sophocles' plays. Fromm might just as well attack modern medicine by proving Hippocrates never lived.

In the case of *Oedipus Rex* itself, Fromm writes: "But there is no indication whatsoever in the myth that Oedipus is attracted by or falls in love with Jocasta."

The reader of *Oedipus Rex* can satisfy himself by merely rereading the speeches between Oedipus and Jocasta that these two are still strongly bound together sexually and that there is no such thing in the play as an indication that Jocasta's going with the throne is "the only reason" for their marriage. The real point, however, is that Fromm is looking for *conscious and explicit* sexual desires in the Oedipus complex, which is an *unconscious* phenomenon! The crucial detail in the play is the oracle predicting that Oedipus will have sexual intercourse with his mother. The oracle of the Greek myths, Fromm has forgotten, is a representation of the unconscious. Even if there were no other indications of Jocasta's and Oedipus' sexual interest in each other than the oracle's prediction, that would be enough.

No doubt Freud was much more cautious in predicting the far future than is Fromm. In the main Freud contented himself with describing the psychological structures as they appear in the society in which we live and are likely to live for some time. I think that Freud would have conceded to Fromm that the Oedipus conflict would be profoundly modified in a society "in which respect for the individuality and integrity of every person- hence of every child- is realized." Freud worked for such a society. He had a passionate belief in human progress and educability. He differed from Fromm in not believing that one contributes to that progress by blinking the demonstrable facts of man's psychology and social heritage which render so difficult the ascent from patriarchal society to the brotherhood of man.

FELIX MORROW

New York, N. Y.

Sirs.

Because of the stature which your magazine has attained since its editorial reorganization, it seems worth while to point out one error in an article in your March, 1949, issue. I refer to the article on the "alarm reaction," discussing Dr. Hans Selye's work. On page 22 the authors present the diet of diabetes as an illustration of the point they are raising. They state. "Diabetes can be completely controlled by a diet low in sugar." It would be more in keeping with the current knowledge of diabetes to change the word "sugar" to "calories." Present-day therapy of diabetes no longer stresses only the reduction of carbohydrate in the diet. Rather, a more normal distribution of carbohydrate, protein, and fat is used, but a reduction in the total caloric value is attempted.

GLEN R. SHEPHERD, M.D.

Kansas City, Kan.

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50 AND 100 YEARS AGO

MAY 1899 "The sealing steamer 'Hope' is to be thoroughly overhauled and repaired preparatory to proceeding northward next month with an expedition for the relief of Lieut. Peary, who went to the Arctic regions last summer with a specially selected party. It is thought that he may now need assistance, as his steamer, the 'Windward,' has been frozen in the ice floes since the early part of last winter."

"Under the directorship of Prof. J. E. Keeler, the activities of the Lick Observatory at Mount Hamilton, Cal., with its magnificent 36-inch refractor, have been vastly increased. The wonderful nebula in Orion, one of the most distant and remarkable objects in the universe, has been of late the subject of patient and protracted observation by Prof Keeler. The spectrum of the nebula, interpreted by our laboratory experience, indicates a high temperature, which, in the case of such enormously rarefied gases, is not easy to understand. We may suppose that the light of the nebula is excited by electrical disturbances, in which case the temperature of the gases may be low; but of these electrical disturbances we have no independent knowledge. The problem is one of many which still await solution."

"Nowhere has the development of automatically propelled vehicles reached a more advanced stage than in France, where, on account of the fine roads and pavements, the most favorable conditions are found for their operation. Carriages and tricycles operated by gasoline motors are now among the ordinary sights in the streets of Paris."

"Prof. Marconi has invented an instrument for ascertaining a ship's position in a fog, when it is within range of one of the telegraph stations. It consists of a receiver which can be revolved and which, when pointing toward the transmitting station, sets off an electric bell, thus establishing the bearings as accurately as a compass can. The instrument is to be tried on the Channel steamers."

"A dainty piece of spectroscopic work by Prof. George E. Hale, director of the Yerkes Observatory, has recently come to light. In the solar spectrum there were long ago recognized bands that indicated the presence of carbon. What Prof. Hale has done is to locate the carbon with precision, and thus to establish its existence beyond a doubt. He found that it was in the lower part of the chromosphere. Prof. Hale is satisfied that the carbon layer is a thin one, and that normally it lies down within five hundred miles of the sun's surface—a conclusion that harmonizes well with the notion that the glow of the photosphere emanates chiefly from particles of solid carbon suspended therein."

"It seems that the medical experts in London are now accepting the conclusions of Prof. Grassi, of Rome, as to the cause of black-water fever, which is one of the worst forms of malarial fever The scientific staff of the Natural History Museum, at South Kensington, are inviting travelers in all countries to collect as many mosquitoes as possible in the districts visited by them, with a view to properly identifying the various species, and tracing out still further the supposed connection between these insects and some of the fevers prevalent in tropical climes."

MAY 1849. "Some cases have recently occurred in which fatal consequences were attributed to the inhalation of chloroform; surgeons have been turning their attention of late to the employment of this powerful sedative locally, in order to deprive of sensation parts intended to be operated upon. A very interesting experiment of this kind was made at the Royal Cornwall Infirmary, England, as related by the Cornwall Royal Gazette. The result was highly satisfactory, and the poor man looked on with the greatest composure, not moving a limb while the diseased part was being removed."

"Patent granted to Samuel F. B. Morse, of Poughkeepsie, N. Y., for improvement in Electric Telegraphs."

"A discovery of a singular and highly important character is announced in Paris by a Prof. Meinike, a German probably, *viz.* an artificial gas confined in glass, assuming, by an electric shock, a permanent, steady light, without heat or combustion!"

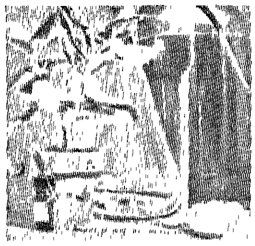
"Faraday has shown, by the most conclusive experiments, 'that the electricity which decomposes, and that which is evolved by the decomposition of a certain quantity of matter, are alike. What an enormous quantity of electricity, therefore, is required for the decomposition of a single gram of water! It would appear that 800,000 charges of a Leyden battery, charged by thirty turns of a very large and powerful plate machine are necessary to supply electricity equal to the quantity which is naturally associated with the elements of that gram of water endowing them with their mutual chemical affinity.' "

"The solar beam has been tortured through prismatic glasses and natural crystals. Every chemical agent has been tried upon it, every electrical force in the most excited state brought to bear upon its operations, with a view to the discovery of the most refined of earthly agencies; but it has passed through every trial without revealing its secrets, and even the effects which it produces in its path are unexplained problems still to tax the intellect of man."

"The grandest Suspension Bridge in the world, we suppose, is one recently completed at the city of Pesth in the dominions of Austria. This bridge was commenced in 1840 according to the design and under the directions of William Tierney Clark, an English civil engineer. It extends over the Danube and has a clear waterway of 1,250 feet, the centre span being 670 feet. The height of the suspension towers from the foundation is 200 feet, but they have 50 feet of foundation in the water."

"There is no class of mechanics in the world that have so much responsibility resting upon them as Steam Engineers. Hundreds of Engineers go on board of boats, or on locomotives, and are then put in charge of a machine they know no more about than the man does about the watch that he winds up, and they have to deal with an agent as subtle as the lightning from heaven. Surely such men as these should not be trusted with so many valuable lives, and such a vast amount of property."

"We may regard the passage of Electricity as instantaneous, so far as any of our senses are concerned; for its velocity is such, that it will start from Woonsocket, make 7 passages around our earth, and reach the Capital of the Chinese Empire on its eighth journey, in the brief space of a single second of time."



THE COVER

The painting on the cover shows some of the effects produced by growth-inducing plant hormones, or auxins (*page 40*). In the flowerpot is a kalanchoe, a tropical plant from Madagascar. The thick growth of roots halfway up its right shoot was induced by an application of the auxin indole-butyric acid. Parachlorophenoxyacetic acid was applied at the same time, resulting in the monstrous growths on the upper part of the shoot. The tomato at the right is a new seedless variety, created by auxin treatment of tomato-plant flowers. Just to the left of it is a tube of human urine, source of the first auxin to be isolated and identified. In the background are a flask and a large bottle of water. The scene of the painting is the laboratory of P. W. Zimmerman at the Boyce Thompson Institute for Plant Research in Yonkers, New York.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
12-15	Hal Fiedler
17	William Auerbach-Levy
18-21	Roger Hayward
23-25	K. Chester
30	U. S Army
33	Willy Ley (*top and bottom left*), Esther C. Goddard (*bottom right*)
34-35	Matthew Greene
37	Jet Propulsion Laboratory, California Institute of Technology
39	U. S. Army (*left*), U. S. Navy—Johns Hopkins Applied Physics Laboratory (*right*)
41-43	A. Brotman
45-47	David Stone Martin
49-50	Eric Mose
52-53	Irving Geis
55	K. A. Clark
56	John Wiley and Sons
60	Mount Wilson Observatory (*left*), *Memoirs of the British Astronomical Association* (*right*)
62	Captain William C. Bryson (*left*), E. B. McCartney (*right*)
63	E. B. McCartney

What GENERAL ELECTRIC People Are Saying

C. G. SUITS

Vice President and Director of Research

RESEARCH EXPLORING: In the days of Daniel Boone a good deal of exploring could be done with a pack horse, a rifle, and some shot and dry powder. The regions of the earth that can be explored with simple equipment have been mostly worked over, however, and the modern Daniel Boone uses airplanes, helicopters, magnetometers, and seismographs to do his work.

The same thing is true of the scientific frontier today. Edison, one of the Daniel Boones of science, was able to make his remarkable inventions with the simple facilities and equipment of the laboratories I have been privileged to see today. But the scientific frontier that can be explored with such simple tools has receded almost to infinity. To explore today's great frontier areas in the nucleus of the atom, the region of supersonic fluid flow, the semiconducting elements, the constitution of complex matter, the infrared radio spectrum, the region of absolute zero, and many others, requires scientific tools and facilities that are correspondingly complex.

Edison Pioneers, East Orange, N. J.
February 11, 1949

★

D. E. CHAMBERS

Executive Engineer, Research Laboratory

INTERNATIONAL COMPETITION: I have often thought that the role played by our technical potential in international competition was powerfully illustrated on the Pacific Islands by the comparison there of the bulldozer in the hands of the American forces and the hand shovel in the hands of the Japanese. It is essential that we keep such comparisons as much as possible in our favor in the future, and to this end we must see to it that our technical knowledge is always at least as good as that of any other nation, for the time factor will be so very short in the future.

We must be sure that our facilities are always at least as up-to-date as those of any other nation. For example, if oxygen can be used substantially to increase the output of steel furnaces, we must be sure that, if possible, we are the first to achieve this result.

We must be sure that we have plant for the quantity production of the items for peace or of modern war. Whether we have this plant depends upon the peacetime buying power of our people—and this depends upon our people having a relatively high standard of living.

We have an increasing need for conserving our natural resources through increasing the efficiency of our machines and through the finding of substitutes for our scarce materials. American industry has already demonstrated its eagerness and its ability to satisfy this need. For example, 50 per cent more kilowatt-hours can be produced per pound of coal than was the case in 1923, and many new synthetic materials such as nylon and artificial rubber have been and will be produced to conserve our national resources and to help free us from dependence upon foreign sources.

U. S Military Academy,
West Point, New York
January 25, 1949

★

J. J. HUETHER

Manager, Central Station Divisions

GAS TURBINES: There is now in operation on a locomotive a 5000-horsepower, single-shaft, simple-cycle, combustion gas turbine, designed to burn bunker C oil . . . The probable success of this unit led to the building of a 3500-kw combustion-gas-turbine generating power plant . . .

A second unit—a 5000-kw high-efficiency power plant—has been designed and will be assembled for test within the next few months. This unit . . . has an over-all efficiency of 28 per cent at the generator terminals, contrasted with 17 per cent efficiency of the simpler 3500-kw unit . . .

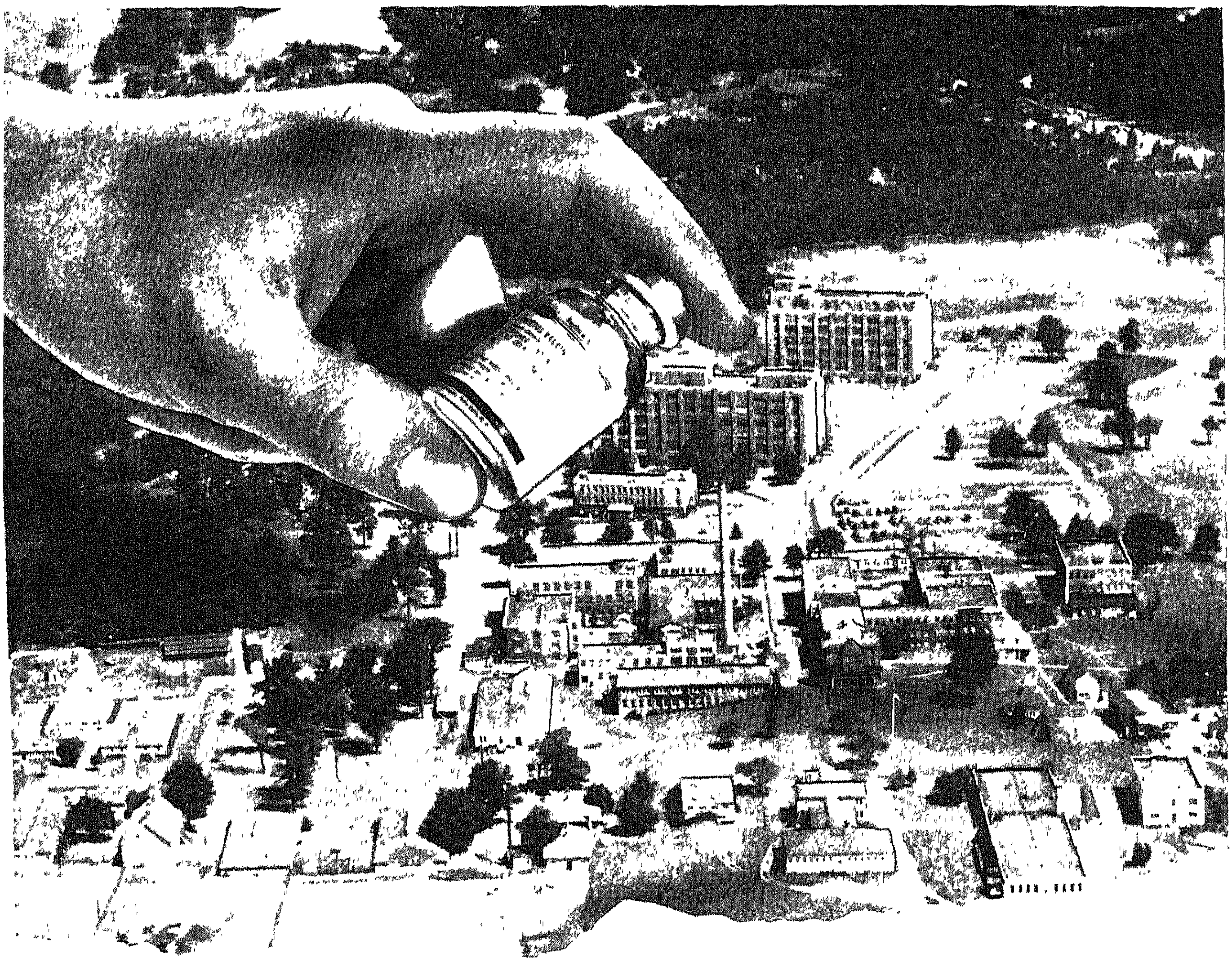
The 5000-kw high-efficiency plant with a fuel rate of approximately 12,500 Btu per kw-hour will ask no quarter from any steam plant of equivalent size and will compare favorably with many larger steam plants in operation today . . .

In this range of capacities, the combustion gas turbine seems to have a definite place as a base-load plant. A second application is in firming up service at the end of a line or in an outlying load center. A third application is as a standby plant . . . It should not be inferred, however, that the combustion gas turbine is recommended as a rotating or spinning standby plant. Its high no-load losses rule it out for this application.

For a fourth application, the compact size and the quick starting ability of the simple-cycle 3500-kw unit would seem to offer an ideal opportunity for portable power plants with railway car mounting for quick transportation to areas which have been wiped out by floods or hurricanes or other catastrophes —or as an emergency shaft to pick up the load in case of a breakage in a transmission line or failure of an existing unit . . .

The stage has now been reached where time and experience are of greater importance than additional orders or development of new designs. The engineers, therefore, are in a condition of restrained enthusiasm, working hard to complete the units now on order and to obtain all characteristics through engineering tests, followed by practical operating experience, to determine such things as maintenance, life, and performance in service.

National Assn. of Purchasing Agents,
Chicago,
February 7, 1949



Increased Life Span for Three Hundred Billion Bacteria

AMONG the many miraculous pharmaceuticals made in the great modern plant of Lederle Laboratories at Pearl River, N. Y., is a preventive for Brucellosis, an infectious disease of cattle, costly to dairy farmers and dangerous to communities as a possible source of undulant fever.

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When originally introduced in liquid form, the life span of the packaged bacteria was only around three months —after that the product was worthless

The short shelf-life made the product costly to manufacturer and consumer. It prevented overseas shipment to foreign markets.

Lederle purchased from DPI high vacuum sublimation equipment for dehydrating the product. This treatment, so well known to DPI engineers, improved the stability and extended the "life" of the packaged bacteria from three months to a year.

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CONTENTS FOR MAY 1949 VOLUME 180, NUMBER 5

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

MAY 1949 VOL. 180, NO. 5

A STUDY OF ATTITUDES

The psychology of U. S. soldiers was thoroughly explored during the war. The findings suggest some rich leads for peacetime social research

by Samuel A. Stouffer

IN July, 1941, the Secretary of War issued an order prohibiting surveys of attitudes of enlisted men. If their attitudes were critical of the Army, the order said, a survey would be "destructive in its effect on a military organization where accepted responsibility on the part of every individual is fundamental."

Five months later, an exception to this rule was permitted. With the personal backing of Chief of Staff George C. Marshall, a group of psychologists and sociologists used anonymous questionnaires to sound out the attitudes of a representative cross section of 1,500 enlisted men in one infantry division in training. The study was made the day after Pearl Harbor. For the first time in any modern army, the new methods of social science research had a chance to show their power in comparison with the reports of visiting officers, who had to get their impressions from haphazard and biased samples of informants.

The report was critical, all right. Straight from the pencils of the men came frank and documented indictments of the training methods, the leadership system, and other activities of an army which was enmeshed in ancient tradition and only beginning to awake to the needs of modern mechanized war. The complaints were not just idle gossip and griping. For example, statistical tables and charts proved that the men were discriminating in their criticisms: some practices were condemned by nine out of 10; some were approved by almost as large a proportion.

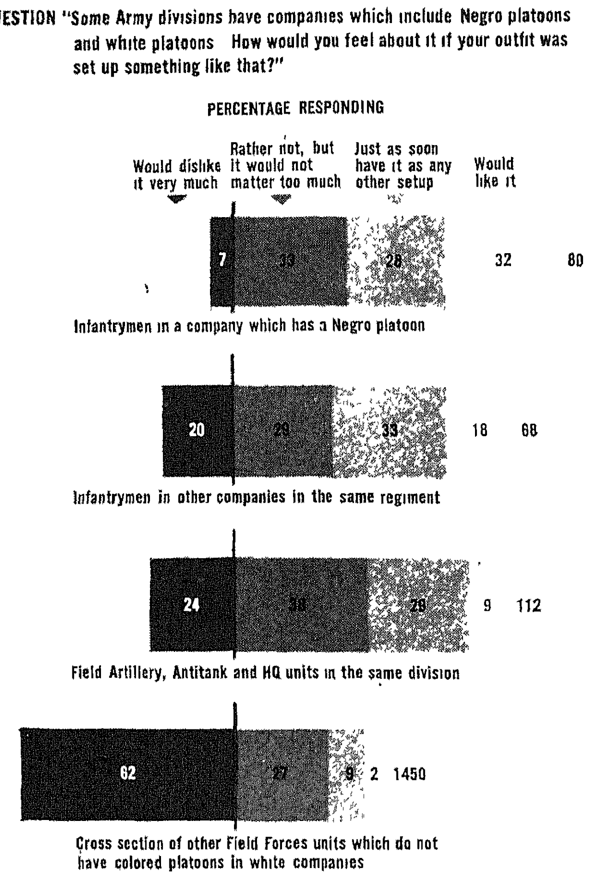
General Marshall himself read the report on this division. So did many of the officers on the General Staff. One general started reading it at midnight and said the next day that it was so exciting and revealing that he did not put it down until three o'clock in the morning. A considerable number of changes were instituted as a result of that one study, including a revision of plans for the new Officers' Candidate Schools. Most important of all, the War Department put such research on a permanent basis. Between Pearl Harbor and the end of the war, the Research Branch of its Information and Education Division made more than 200 surveys of representative samples aggregating over half a million U. S. enlisted men and officers.

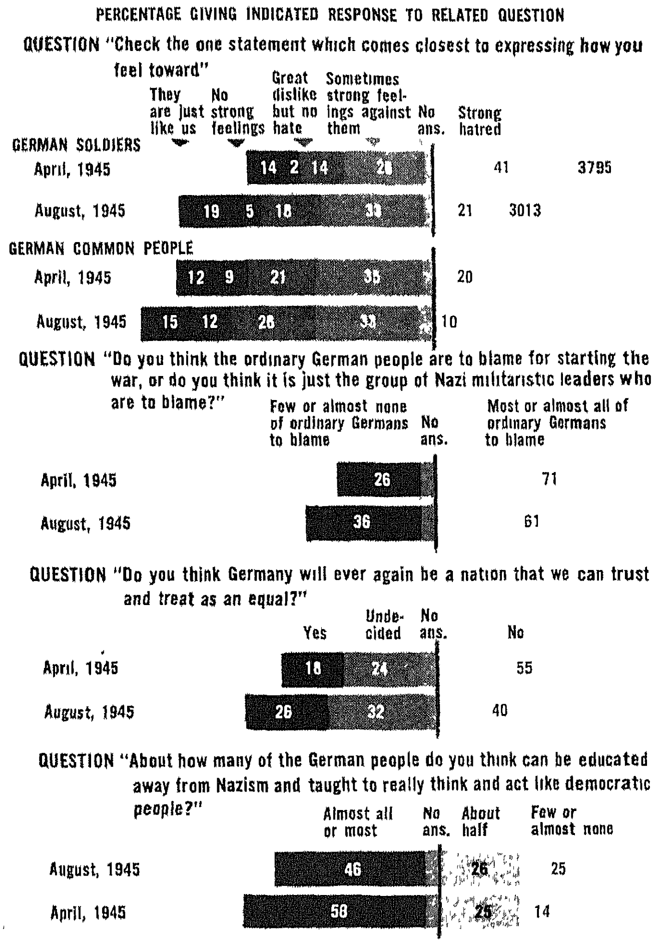
> EDITOR'S NOTE
>
> During the war the author of this article was head of the professional staff of the Research Branch in the War Department's Information and Education Division. The work of the Research Branch was one of the largest social-science investigations ever made. The Princeton University Press is now publishing the results of this unprecedented undertaking in four volumes. The first two volumes are now at book stores. Volume III will be ready this summer, Volume IV in the fall. The title of the series is *Studies in Social Psychology in World War II*. The volumes:
>
> I. *The American Soldier: Adjustment During Army Life*
> II. *The American Soldier: Combat and its Aftermath*
> III. *Experiments on Mass Communication*
> IV. *Measurement and Prediction*

The Army had opened up a new channel of communication. The top command now could replace guesswork about some of the morale problems with evidence. To be sure, not all officers welcomed it. There was always opposition, but skepticism diminished as the war progressed. The standard argument that it would "upset a man's morale" to give him a chance to say frankly what he thought without fear of reprisal was easy to refute with evidence.

Moreover, it was possible to show that these surveys, using the best methods available to social science, got down to some solid realities. They proved to be of value in predicting the performance of groups of men in combat. For example, before the Normandy invasion all the enlisted men in the 108 rifle companies in four divisions were studied in England. An attitude or morale index was constructed for each company. After two months of fighting in Normandy, each company's record was compared with its pre-battle attitude index. The criterion of its behavior under the stress of combat was taken to be its noncombat casualty rate, because many if not most of the noncombat casualties at this period were psychiatric in character, and some companies had much higher noncombat casualty rates than others. Comparing the three rifle companies with the worst attitude index with the three rifle companies with the best index in each regiment, we found that on the average the companies with the worst indexes before combat had 60 per cent more nonbattle casualties in Normandy than the companies with the best.

THE surveys were applied to hundreds of problems, many of which do not loom large in the perspective of total war, but were important at the time. Why did men in malarial regions fail to





TECHNIQUE OF SURVEY and results are illustrated in this chart of white soldiers' attitudes toward serving with Negroes. Men were polled by questionnaire. Number at right of bar shows size of sample polled.

ATTITUDES TOWARD GERMANS were measured by this series of questions asked U.S. soldiers in the European Theater in April and August, 1945. The results show a measurable drop in hostility after war's end.

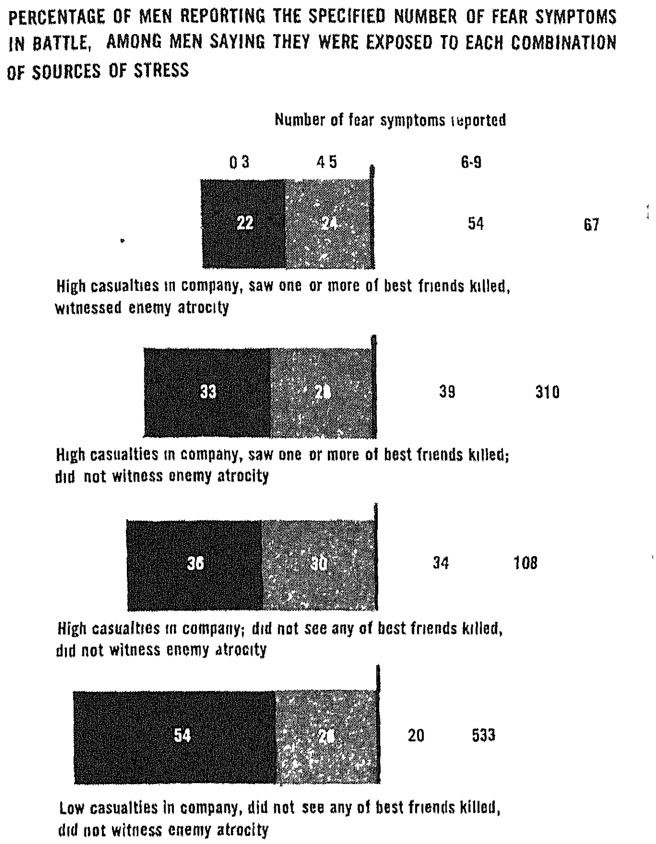
use Atabrine as regularly as they should? What attitudes and practices were associated with trench foot? Which of two kinds of huts did men in Alaska prefer? What were the favored types of winter clothing among front-line troops in Belgium, Luxemburg and Germany? What radio transcriptions did men want? What did they like most to read in *Yank* magazine? What about needs for athletic equipment? What could be done to improve a difficult laundry situation in Panama? What were the sources of difficulties in soldiers' relations with the French? Such inquiries were routine and were made in increasing numbers

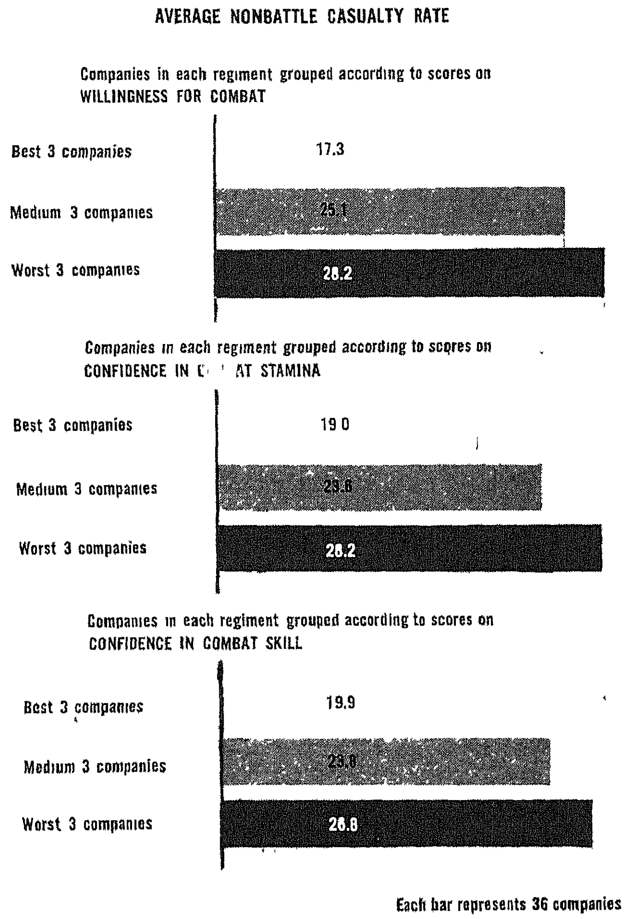
Some of the larger-scale enterprises were. Studies of soldiers' postwar plans, which provided a factual basis for drawing up the GI Bill of Rights; studies of psychiatric screening which led to the development by the Research Branch, in cooperation with the Surgeon General, of a test that was used routinely in all induction stations in the last year of the war; special surveys of the Air Forces and of other large components of the Army such as the infantry (the idea of the Combat Infantryman's Badge grew out of one of these studies); analyses of problems of occupying troops, which led to changes in occupation policy in Germany.

One of the most useful researches was the one that established the point system for demobilization at the end of the war. The President and the War Department decided that the order of demobilization should be determined in terms of what the soldiers themselves wanted. The idea of a point system was conceived in the Research Branch Representative samples of men throughout the world were queried, and from their responses the variables of length of service, overseas duty, combat duty and parenthood emerged as most significant. The final weights assigned to these variables yielded point scores which had a close correspondence with the wishes of the maximum number of soldiers, even if they did not exactly reproduce these wishes. Studies of reactions to the point system showed that the response to it was remarkably favorable, except among minorities who felt they were personally most injured by it (for example, combat infantrymen) Even after many men became angered by the alleged slowness of demobilization, the majority, though hostile to many if not most Army policies, continued to approve the point system (which determined the order, not the rate, of demobilization) In view of the explosive tensions in the early demobilization period, historians may find that the establishment of an objective system whose justice was accepted by most men saved the country from what could have been a crisis seriously damaging to American prestige.

PLAINLY the findings and the experience gained from these many surveys are not limited to the military sphere or to wartime application. While these were all studies of men at war, they have implications of general social importance. For social scientists their chief present interest lies in the question of how the findings and techniques that were developed can be applied to civilian institutions.

One important problem to which they may be applied, for example, is that of increasing job satisfaction. In World War I psychologists first measured *aptitudes* on a large scale, with such crude devices as the Army Alpha test. Out of that work came hundreds of psycho-





FEAR IN BATTLE depended directly on the number and closeness of casualties previously witnessed by the soldier questioned. This survey was made among combat veterans in an infantry division in the South Pacific.

PRE-BATTLE MORALE measurements showed good ability to predict how men would behave later in combat. Companies with highest scores on the morale index had fewest nonbattle (neuropsychiatric) casualties.

logical studies in the years between the wars. By World War II psychology was ready with improved techniques of measurement and classification to aid in the selection of airplane pilots, navigators and bombardiers, and to assign soldiers generally on a basis that took account of their abilities. But satisfaction and efficiency on the job depend on more than aptitudes. They depend also on the interests and motivations of men.

In World War II the Research Branch found that aptitudes and attitudes were like the two blades of a pair of scissors. Men who got a chance to volunteer for their specific assignments were much better satisfied than those who never got a chance to choose, even though many of the latter actually were using their civilian skills. It would have been possible for the Army to extend the range of freedom of choice much further. In the future, in civilian industry as well as in the armed forces, it is likely that much more attention will be given to such attitudes. More can be done to glamorize unpopular jobs—the Navy may have shown how to do this with its Seabees.

One of the most important concepts used in the Research Branch was the principle of relative deprivation. This idea reconciled many otherwise paradoxical findings, not only in the field of job satisfaction but elsewhere. For example, two of the most extreme branches of the Army as far as promotion opportunities were concerned were the Air Forces and the Military Police. The Air Forces were full of sergeants and corporals. The MPs were mostly privates. Yet men in the Air Forces complained of lack of promotion opportunities more than did those in the Military Police. Why? The concept of relative deprivation led to an answer. Since most Air Forces men got promotions, those who did not tended to be personally aggrieved. Since few MPs got promotions, those who did not had so much company that they did not take it as a personal injustice. MPs who were promoted were so few that the promotion was a matter of exceptional pride. In other words, one's deprivation was always viewed relative to that of others, and the research problem was to find out who the "others" were

Almost everyone expected that Northern Negro soldiers stationed in Southern camps would be more dissatisfied than those stationed in Northern camps. It is true that those sent South did complain, often bitterly, of Jim Crow regulations and of treatment by the local police. But in general their morale was as good as or better than that of Northern Negroes stationed in the North. Why? After elaborate cross-tabulations that eliminated education and other factors as the explanation, it finally appeared, as should have been seen earlier, that relative to civilian Negroes in the South the Negro soldier apparently perceived himself to be well treated. But when a Northern Negro at a Northern camp compared himself with civilian Negroes making big money in the war industries, he apparently felt himself not so fortunate.

In spite of intense eagerness to get home, the job satisfaction of soldiers in the rear areas of active theaters overseas was as high as or higher than that of men doing the same kinds of jobs in the U.S. Why? Part of the explanation, of course, was the sense of the importance of their overseas mission. But another significant aspect appears to be the fact that, relative to the combat troops they knew, the rear-area men had jobs which,

though often unpleasant, tended to be safe. Very few were found who had the desire to change places with the combat men.

On the other hand, these rear-area troops and soldiers in overseas noncombat areas such as Panama, Alaska, Iran and most of India-Burma were the most vocal of all in their criticism of officers. Why? Analysis of many studies all over the world indicated that one of the basic factors in enlisted men's antipathy to officers related to the special privileges of rank, which involved many practices alien to American democratic traditions. If the supply of attractive women, liquor or entertainment was severely limited, as was often the case overseas, the problem of equitable distribution became acute. If, as was charged, the officers tended to monopolize such desired objects, the men's resentment is understandable. There was even greater scarcity of these attractions in the front lines, but there the officers and men shared the same deprivations. At camps in the U.S. there was less deprivation; therefore the so-called caste system, though productive of much irritation, was not as heavily criticized there as in places where the relative deprivation of enlisted men as compared with officers was greatest.

ALL this has significant implications for civilian life. In industry, or in the family, or wherever we are, satisfaction is a relative matter. The key to understanding a given attitude is to learn the context in which the attitude is expressed and the standards of comparison that exist in the given situation.

These studies also made clear the importance of studying what the sociologist calls informal social controls. Perhaps few organizations have more elaborate formal rules than the Army, but in the last analysis, in the Army as elsewhere, the most powerful control is that of one's own fellows. Some searching analyses were made of the process of "goldbricking"—that is, appearing to be busy without really accomplishing much of anything. Goldbricking, an older word for which, significantly, is "soldiering," sometimes was practiced with so hearty a group spirit that it represented high morale from the standpoint of the group—though not from the standpoint of the Army command. Studies showed that there were clear-cut codes about goldbricking. A soldier who refused to conform to the code was a target for scorn from his fellows; on the other hand, when the group felt that a given task was necessary or that the group would be punished if it were not fulfilled, then an individual goldbricker became an object of scorn.

A long series of studies of combat troops, based on thousands of systematic interviews and on personal front-line experiences of Research Branch members, emphasized the central importance of such informal controls, or group opinion, in stress situations. Compared with the feeling that one must not lose face in the eyes of one's fellows or let them down, patriotism, hatred of the enemy and other stereotyped explanations of what keeps a person going in combat seem to have been negligible factors.

One of the greatest weaknesses of social science has been the infrequency of its use of deliberately designed controlled experiments, which are the only sure method of determining whether a change in one variable actually will be followed by a change in another. From the beginning of the war the Research Branch recognized the need for such experiments. But neither the Army nor the U.S. public in general has been in the habit of asking for this kind of evidence from social scientists. Although the Army would not think of adopting a new weapon without exhaustive trials, it was not nearly as ready to try out a new social idea—such as a different personnel policy or a different training method—on a very limited scale, with careful controls to measure exactly what the effects would be.

There were instances in which the Research Branch was able to obtain a kind of experimental proof, even in situations that were not deliberately set up as controlled experiments. For example, the Army tried out in Europe the radical idea of placing an entire platoon of Negro volunteers in a white infantry combat company. This was done in several divisions, most of which saw several months of subsequent battle. At the end of the campaign interviewers polled sample groups of men in several divisions to find out how the attitudes of men who had served with Negroes compared with those of men who had not. In divisions that had no mixed companies, 62 per cent of the soldiers said they would dislike very much to serve in the same companies as Negroes. Of white infantrymen who had fought in the same divisions but not the same companies as Negroes, only 20 per cent said they would dislike it very much. And among white infantrymen who had actually been in the same companies as Negroes, only 7 per cent said they disliked it very much.

There was another very interesting finding. Two thirds of the white men in the mixed companies, when polled after the experience, said that they had been opposed to the scheme beforehand and had thought it would fail. This was almost exactly the same proportion of opponents as was found in divisions that had not experienced the plan; in other words, the retrospective answers about attitudes corresponded closely to those of groups reporting current attitudes, so one finding tended to confirm the other. The findings can therefore be considered, cautiously of course, to approach in reliability the result of a controlled experiment, although it falls far short of the ideal.

EARLY in the war the Research Branch sought a full-fledged opportunity to demonstrate the value of controlled experiments. This opportunity came in connection with the physical training program.

A committee of physical educators had proposed a new physical conditioning program for the Army, based on modern experience in training football players and other athletes. They believed that the traditional Army regimen of setting-up exercises and hikes was uninteresting to the men, time-consuming and generally inefficient. A Research Branch survey of samples of troops throughout the country, using tests of physical proficiency devised by the committee, confirmed the criticism. It showed that men who had been in the Army six months to a year and had been subjected to the old-fashioned conditioning system made little better scores on tests of strength or of stamina than did new recruits. That the tests were valid measures of physical condition was confirmed by the fact that paratroopers, initially selected for ruggedness and subjected to particularly rigorous physical training, were able to make high scores on them.

A controlled experiment was then set up. Two samples of new recruits, matched on initial proficiency tests, were selected. One sample was put through the conventional Army course of calisthenics and hikes. When retested the group showed only a slight improvement over its initial scores. The other group was given the rigorous new program of training. After six weeks its proficiency scores were far superior, almost as high as those of the paratroopers. Moreover, the men getting this training liked it better than did those in the traditional program. The results persuaded the Army to scrap its traditional procedures and introduce the new program on an Army-wide basis.

While the hopes that this demonstration would induce the Army to try other experiments in handling its human resources were not fully realized, the use of controlled experiments became an important part of the developmental work of the Information and Education Division. One of the functions of this Division was to make motion picture films to give the soldiers better orientation to the war. The "Why We Fight" series of films, produced under the direction of Colonel Frank Capra, was studied in detail. Analyses were made by the attitude-survey method of the effectiveness of the films in general, the differential effects on different types of soldiers and

the impact of specific elements of film content.

Experimental studies also were of use in testing theories on propaganda techniques. For example, is propaganda more effective when it tries to present an opposing point of view and refute it than when it merely reiterates one's own position, *à la* Goebbels? Experimental studies made in the Research Branch suggest that the answer may be yes and no. Presenting both sides seemed to be more effective for winning the better-educated soldiers to the point of view wanted, but less effective among the less educated. The latter tended to get from the two-sided presentation doubts that they might not otherwise have had.

One of the chief obstacles to carrying out controlled experiments is the lack of good criteria of measurement. For example, the Research Branch made extensive studies of fear among soldiers. Thousands of combat men were interviewed. Some experiments were carried out, notably at the school for training paratroopers. But even at the end of the war there was no reliable answer to the following question: Is it better to scare combat soldiers badly from the beginning of their training, to lead them gradually into more and more frightening situations, or not to scare them at all? What complicates the problem is that fear may have either harmful or useful effects: It may freeze a person or cause him to act erratically or run away; on the other hand, it may make him more attentive to danger signals and selective of those to which he must respond in different ways. The trouble is that we have as yet no good criteria for measuring fear and evaluating its adaptive value.

A good case can be made for the hypothesis that this lack of measured criteria is one of the main reasons why experimentation in the social sciences is so rare as compared with the physical sciences, and why the social sciences have moved so slowly. Medical science made similarly slow progress until modern instruments of biological measurement were developed. The Research Branch made some new attacks on the measurement problem in social psychology and sociology, and a considerable part of its report is devoted to a fresh analysis of measurement theory which, it is hoped, will stimulate concerted efforts in this direction. Another decade or two of accumulated experience is likely to see great improvements in social science, particularly as more and more of the newer students get a hardheaded training in mathematics, statistics and the design of experiments.

Samuel A. Stouffer is professor of sociology and head of the Laboratory of Social Relations at Harvard University.

(a) After the war when the Army starts releasing soldiers back to civilian life, which of these two groups of men do you think should be released *first?* (Check *only* one)
____ Men with dependents
or
____ Men over 30 years of age

(b) Which of *these* two groups of men should be released *first?* (Check *only one*)
____ Men who have been in the Army longest
or
____ Men with dependents

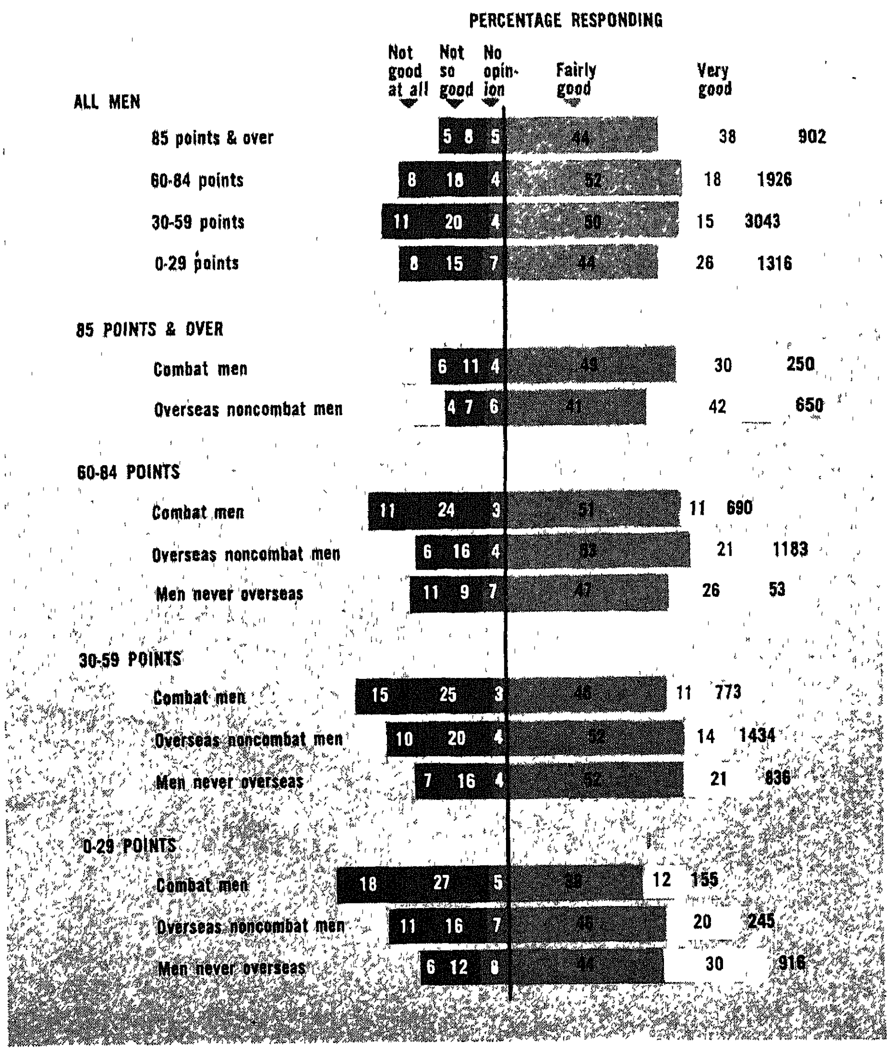
(c) Which of *these* two groups of men should be released *first?* (Check *only one*)
____ Men over 30 years of age
or
____ Men who have served overseas

(d) Which of *these* two groups of men should be released *first?* (Check *only one*)
____ Men who have served overseas
or
____ Men who have been in the Army longest

(e) Which of *these* two groups of men should be released *first?* (Check *only one*)
____ Men over 30 years of age
or
____ Men who have been in the Army longest

(f) Which of *these* two groups of men should be released *first?* (Check *only one*)
____ Men with dependents
or
____ Men who have served overseas

QUESTION "In general, what do you think of the Army Score Card Plan (the point system)?"



POINT SYSTEM for demobilization was based on preferences of soldiers as expressed in world-wide poll (*above*). Most GIs later approved system adopted, but approval varied somewhat with the individual circumstances.

PAULING AND BEADLE

Two investigators at the California Institute of Technology have laid the groundwork for an unusual partnership of chemistry and biology

by George W. Gray

MORE than four centuries have passed since Paracelsus of Hohenheim gave scientific medicine its charter in his celebrated hypothesis: *The human body is a conglomeration of chymical matters, when these are deranged illness results, and naught but chymical medicines may cure the same.*

It has taken man a long time to learn even a small part of these "chymical matters." As recently as 1849 the molecular weight of water was so uncertainly known that this principal ingredient of the body's conglomeration was still being written as HO by many chemists. Indeed, the idea that each atom has a definite combining power was yet to be accepted. Now the situation has changed. Biochemistry is today the principal battleground of science's attack on disease. The wealth of physiologically-useful chemicals whose identification came out of these studies—such compounds as the vitamins, the hormones and the antibiotics, to name but three groups—provides powerful evidence in support of the Paracelsian doctrine and has spurred research in hundreds of universities, medical schools, and institutes.

A recent visit to the California Institute of Technology gave me the opportunity to see at first hand a striking example of the present-day partnership of chemistry and biology—a union which has been solemnized at the Institute in a large new joint project of its chemical and biological divisions. The chemists and biologists here are not consciously seeking for new vitamins, new hormones, new antibiotics, or any other specific nutritional or therapeutic agent. Their quest is for more fundamental knowledge. They are conducting a systematic search into the ways in which the body's molecules behave. And because the living process is always associated with huge molecules comprising hundreds, thousands, and even tens of thousands of atoms in a single structure, the program at the Institute is being focused primarily on these giant molecules. Their attractions and repulsions, their combinations and modifications, their breakdown into smaller units and the joining of these into new combinations—it is such goings-on that the Pasadena scientists are prying into with all the techniques that chemistry can bring to reinforce those of biology. Their inquiry is directed at the most fundamental of all biological processes: reproduction, nutrition and growth, each studied at the molecular level.

Biochemistry has two avenues of approach. One may enter it from either the biological side or the chemical, and usually the main strength of a research program comes from one or the other of these two directions, seldom from both. A remarkable aspect of the dual project at Pasadena is its balance. This is not a case of a biological laboratory adding a chemical department to its facilities, nor yet that of a chemical laboratory taking an interest in biological problems. It is, rather, a joining of forces between two coordinate divisions, each of which is a leader in its field.

THE Division of Chemistry at the California Institute was founded by Arthur A. Noyes, who had previously served as acting president of the Massachusetts Institute of Technology. He was a physical chemist; his emphasis was on the inorganic aspects of the science, and aspiring chemists from all over America came to California to study the fundamentals under the master

Among these students was Linus Pauling, a recent graduate of the Oregon State Agricultural College. Perhaps Noyes saw in him the man he wanted to train as his successor. At all events, the young Oregonian became a favorite pupil, spent three years of advanced study under Noyes, and was so imbued with the physical aspects of chemistry that he seriously considered specializing in atomic physics. A National Research Fellowship enabled Pauling to spend a year in Munich with one of the world's leading theoretical physicists, Arnold Sommerfeld, and these studies were continued the following year with Niels Bohr at Copenhagen and Erwin Schrödinger at Zurich. But the problems that made the strongest appeal to him were in chemistry, so Pauling remained a chemist, meanwhile continuing his investigation of the forces that operate between atoms and molecules, a study which resulted in his great book *The Nature of the Chemical Bond.* The California Institute of Technology made him a full professor in 1931, when he was only 30 years of age, and following Noyes' death in 1936 Pauling was appointed to succeed him as chairman of the division and director of the chemical laboratories.

"I was a physical chemist," explained Dr. Pauling, "with this dominating interest in the forces which cause atoms to join into molecules and molecules to react with one another. The forces are electrical, of course, and depend on the number of protons and electrons present and the order of their arrangement in the structures. This is essentially a physical subject; or, rather, it belongs to that borderland where chemistry and physics merge In these investigations I naturally selected the simpler molecular structures to work with, such as the metals and inorganic compounds; but in the course of the research I also tested an organic substance whose molecule is large and complicated—the hemoglobin which gives the blood cells their red color. I found that in arterial blood the hemoglobin was repelled by a magnet, but in venous blood it was attracted. This led to a study of the chemical bond between the hemoglobin and the oxygen which it picks up in the lungs. I wanted to consult someone who had specialized on hemoglobin and found the authority in A. E. Mirsky of the Rockefeller Institute for Medical Research. Mirsky came to the California Institute for a year, and we collaborated on a study which resulted in a joint paper."

This paper attracted the attention of Karl Landsteiner, the discoverer of blood types, and Landsteiner asked Dr. Pauling if his theory of the chemical bond

could throw light on a certain antibody reaction. Landsteiner's request introduced Pauling to the highly complicated specialty of immunology. The two men became close friends and frequent conferees on the subject. "From that time on," said Pauling, "I gave a great deal of thought to the chemical aspects of immunology, trying to understand, in terms of the chemical bond, how an antibody neutralizes a virus or other antigen." By 1939 he had arrived at a chemical picture of the reaction and reported his results to the American Chemical Society as "A Theory of the Structure and Process of Formation of Antibodies."

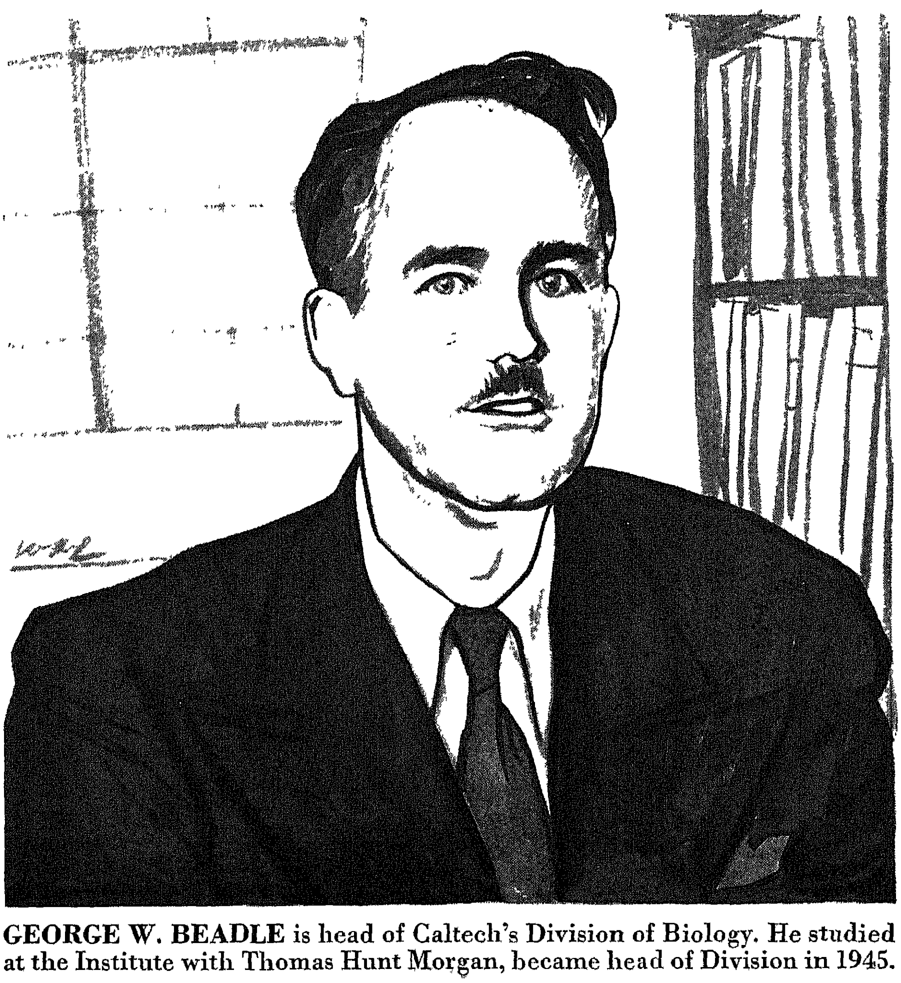
Thus under Pauling the chemistry division at the California Institute added to its program the investigation of hemoglobin, antibodies and other molecular giants that originate only in living systems, while still continuing the basic work in the chemistry of inorganic and simpler organic substances.

MEANWHILE a transition was also taking place in the Institute's Division of Biology. This division had been organized in 1928 by Thomas Hunt Morgan, who had left the chair of experimental zoology at Columbia University to pioneer this new planting in California. Like Noyes in physical chemistry, Morgan was already world-famous in genetics; and his coming to Pasadena brought several strong additions to the faculty, most of them geneticists, and attracted from all parts of the country students who wished to specialize in this science.

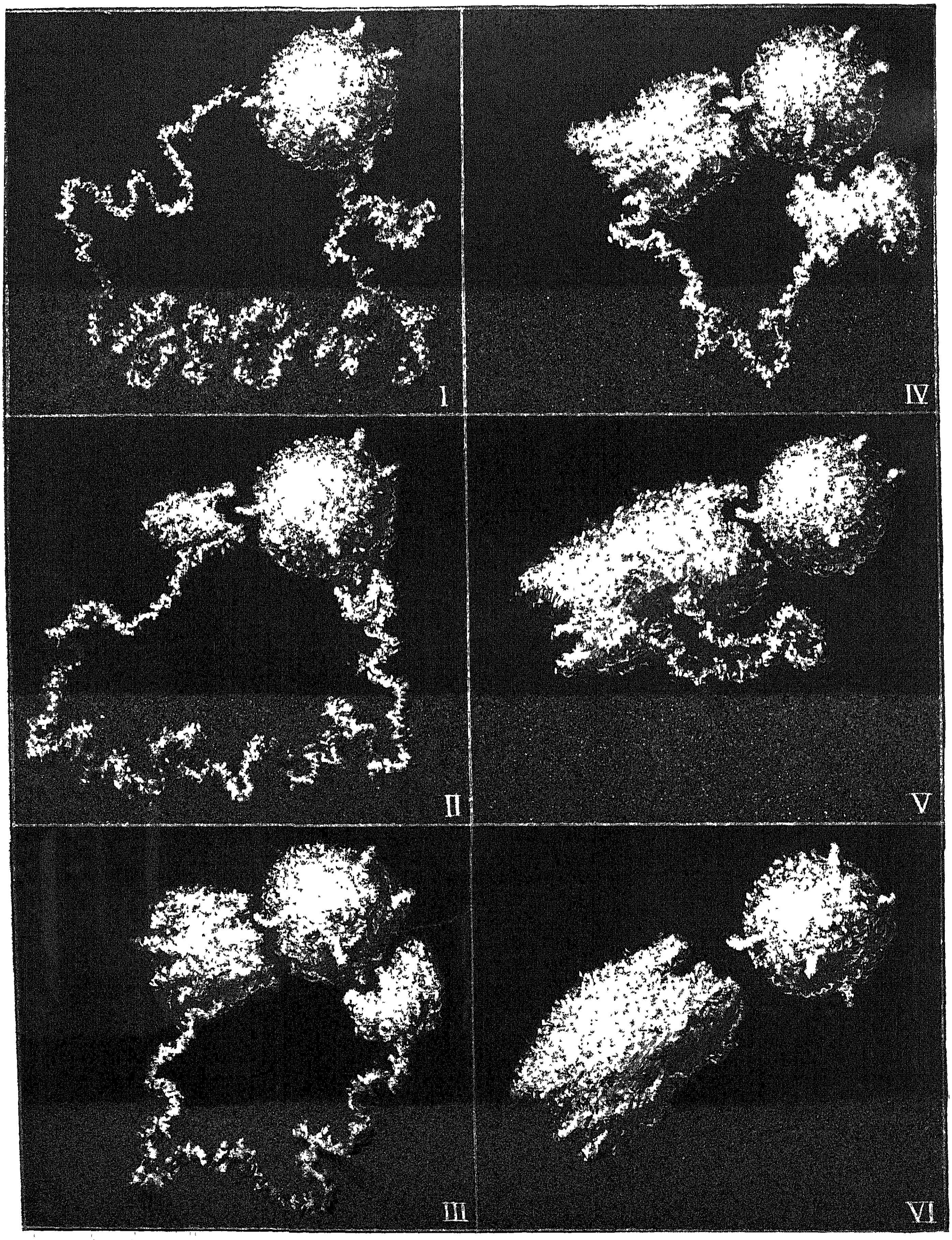
Genetics lends itself to mathematical treatment more easily than most biological sciences, and perhaps it is rightly called the most "physical" of the branches of biology. Certainly Morgan had a strong urge toward collaboration between biology on the one hand, and chemistry, physics and mathematics on the other. After Morgan's retirement in 1941, the biological division was administered for several years by a temporary staff committee. Toward the end of 1945 a successor to Morgan was found in the person of Stanford University's professor of genetics, George W. Beadle.

Beadle's history had closely paralleled that of Pauling. Both men had been National Research Fellows; and as Pauling had come to the California Institute to study under Noyes, so Beadle had come to study under Morgan. It is also significant that at the time when Pauling was turning his attention more and more to the biological molecules, Beadle was becoming interested in chemistry as the handmaiden of genetics. During his 10 years at Stanford he had devoted most of his research effort to experiments with the bread mold, *Neurospora*, and was able to demonstrate in this lowly fungus that the processes of nutrition are directed by the genes. Perhaps it is not

LINUS PAULING is head of Caltech's Division of Chemistry. He first came to the Institute from Oregon State College, was made a full professor at 30.



GEORGE W. BEADLE is head of Caltech's Division of Biology. He studied at the Institute with Thomas Hunt Morgan, became head of Division in 1945.



FORMATION OF ANTIBODY may proceed somewhat as shown in these drawings. Antigen molecule here is a roughly spherical structure of atoms. Precursor of antibody molecule is a long polypeptide chain. Two ends of the chain are folded to fit characteristic parts of the antigen (II, III, and IV). Two fitted ends are then joined by further folding (V). Final antibody (VI) is able to combine with two antigens to form clumps.

undue praise to say that Beadle's work with the mold did more than any other research to establish the chemical nature of genic action.

With chemical research in charge of a biologically-minded chemist, and with biological research placed under the direction of this chemically-minded geneticist, the California Institute now offered an unusual opportunity. The Divisions of Biology and Chemistry immediately prepared a prospectus outlining "a joint program of research on the fundamental problems of biology and medicine." The program would occupy 15 years and would involve considerable enlargement of staff Application was made to philanthropic foundations for support. It was estimated that about five years would be required to bring the program to its full operating capacity. As interim grants to assist the work during the "retooling period," the Rockefeller Foundation appropriated $50,000 in 1946 and an equal amount in 1947, following these in 1948 by a long-term appropriation of $700,000 to be paid in annual installments of $100,000. Thus $800,000 has been committed by this one agency within the last three years. In addition, the project has attracted support from other sources. It is getting $60,000 a year from the National Foundation for Infantile Paralysis, and lesser grants from The Nutrition Foundation and the Hermann Frasch Foundation. The work occupies an important place in the budget of the Institute, and by 1951 it is expected that this research will entail annual expenditures of $400,000.

OF the two essentials to successful research—manpower and equipment—the human element is of course the more important. What makes the situation at the California Institute challenging is the presence there of the two staffs of scientists with their already integrated teamwork of biology and chemistry. In 1946, when the joint program was projected, the staff in biology, including all workers from professors to research fellows and assistants, was made up of 32 persons; and the corresponding groups in chemistry totaled 86. At present biology is employing the services of 79 and chemistry 97, a grand total of 176 for the two divisions, or an increase of 49 per cent over the status of three years ago.

Among the recent staff additions are John G. Kirkwood in chemistry and Max Delbrück in biology. Kirkwood is in the distinguished line of physical chemists He was Todd Professor of Chemistry at Cornell in 1948 when called to the newly established Arthur A. Noyes professorship of physical chemistry at the California Institute. Like Dr. Pauling, he has a predilection for the giant molecules, and recently developed a new type of electrophoresis apparatus with which to study their properties. Tests made at Pasadena within the last few months show that the Kirkwood apparatus will separate the proteins of blood plasma to a finer degree than any other device heretofore used.

Delbruck is a physicist turned biologist. His primary training was in Germany in theoretical physics, but he became interested in bacteriology and came to the U S. as a Rockefeller Fellow in biology. He has made many contributions to our knowledge of bacteriophages, the invisible viruses which prey upon bacteria (SCIENTIFIC AMERICAN, November, 1948). The viruses occupy a borderland between the living and the nonliving, between biology and chemistry, and study of them constitutes an important part of the joint program. Delbruck joined the Institute faculty in 1947, coming from Vanderbilt University.

Among the specialized researchers on the combined staffs is Laszlo Zechmeister, formerly of the University of Pécs, Hungary, who came to the Institute as professor of organic chemistry in 1940. Zechmeister is an authority in chromatography, an amazing technique for separating organic pigments out of mixtures—and his specialty is contributing directly to the joint research program. Another worker is Dan H. Campbell, an immunochemist, brought here in 1942 from the University of Chicago. Campbell has been collaborating with Pauling in an effort to synthesize antibodies by direct chemical means—a daring project which if successful may revolutionize the control of infectious disease.

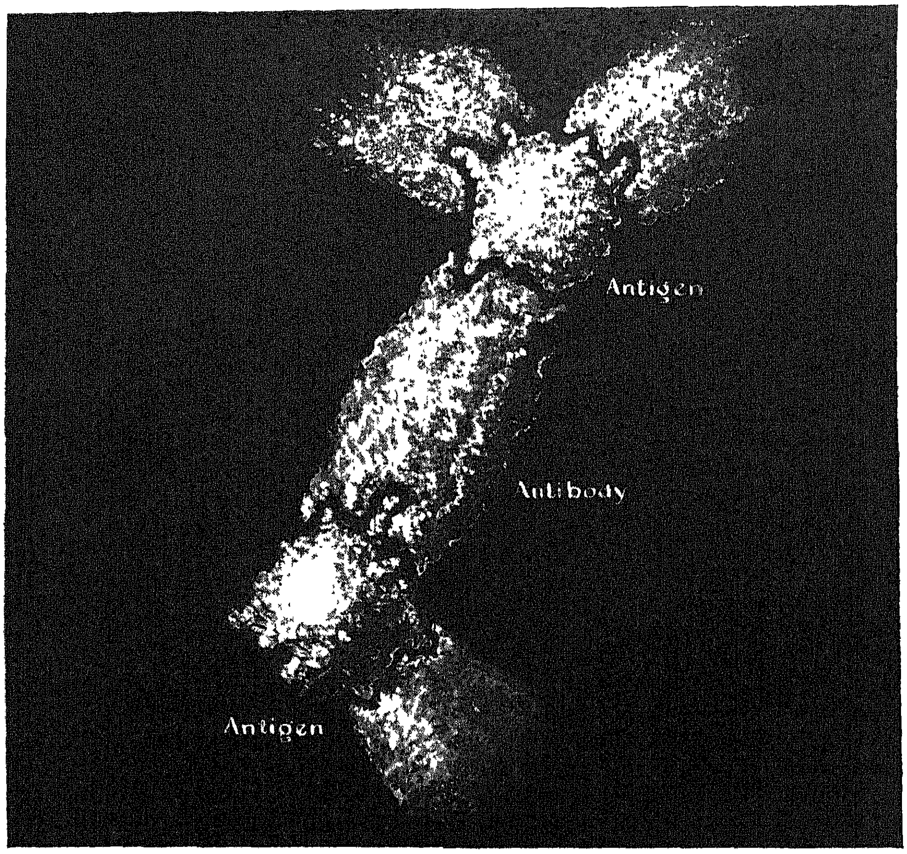
The plant and equipment of the combined divisions are already impressive, and additions are planned. Besides the main chemical and biological laboratory buildings, which adjoin each other, there are three off-campus laboratories of plant physiology, greenhouses, a 10-acre farm devoted to the study of genetics in corn, a marine laboratory at Corona del Mar on the Pacific shore, and a large new underground animal house on the Institute campus. Construction of a new $2 million building, which will be used for the joint chemistry-biology program and will increase the research quarters of the two divisions by 75 per cent, may begin this year.

"WE are seeking to uncover the principles that govern fundamental processes of life," explained Beadle. "If we could do so, the solution of practical problems in medicine would follow inevitably." Therefore, the researchers are studying genes, antibodies, viruses, hormones, biological pigments, and related structures. How does each behave biologically, and how can this behavior be accounted for chemically? Chemical behavior is related directly to the molecular structure of the reacting substances: therefore one of the principal objectives of the program is chemical analysis. What are the building blocks that enter into the construction of genes and the other molecules? How are these building blocks put together, in what order of arrangement, and what are the resulting size and shape of the structure?

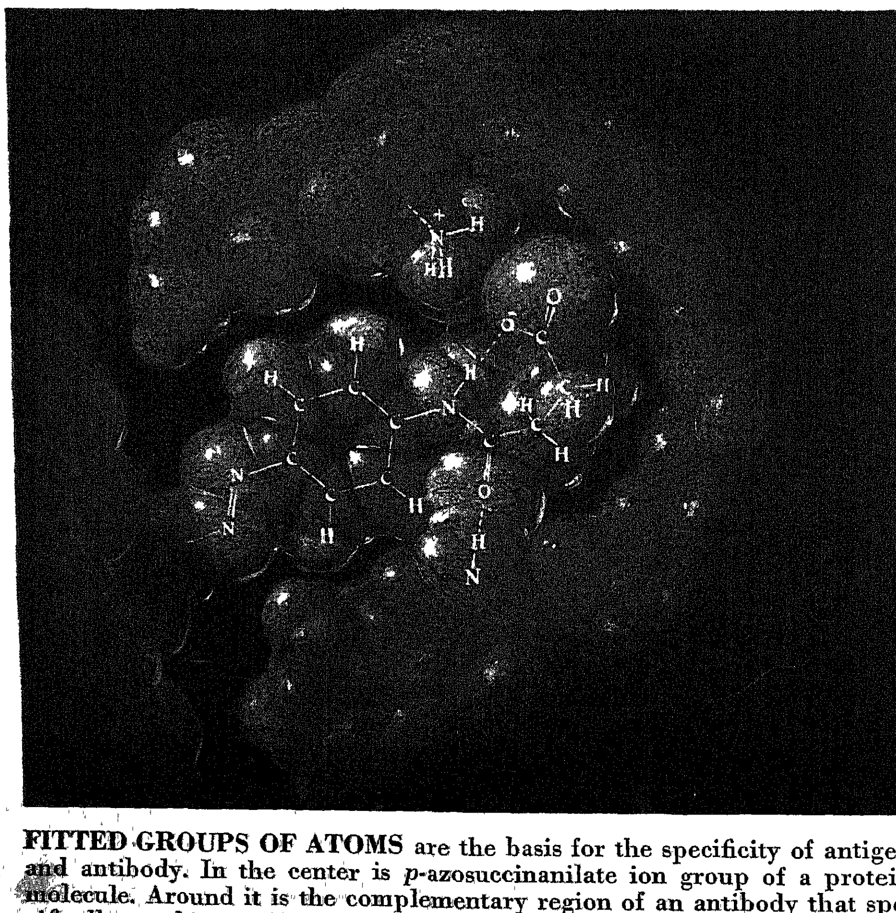
"Science is still far from completely analyzing these biological agents," said Beadle, "but the investigations tend to show that the molecular form known as protein is the key structure Apparently most of the bodies that we are studying in our program are either simple proteins or conjugated proteins."

Simple proteins are simple only by contrast with the vaster architecture of the conjugated molecules. Actually, a "simple" protein consists of hundreds, sometimes thousands, of atoms. When placed beside familiar inorganic molecules, such as those of water, sulfuric acid, ammonia, and table salt, even the smallest protein molecule is like a whale among minnows. But a protein *is* simple in this respect: when reactive agents are applied to break down its molecule, the molecule does not separate into its hundreds or thousands of individual atoms, but divides into characteristic groups of atoms which the chemists know as amino acids. It is as though when a house was demolished, it broke up into basement, rooms and attic, rather than into individual bricks and boards. Twenty-three different amino acids have been found in proteins, and the possible combinations that may be formed from these 23 building blocks run into millions. It is no wonder that proteins occur in the wide variety which makes one man's meat another man's poison. But a number of the most familiar and wholesome substances of the body's equipment are simple proteins. pepsin and many of the other digestive enzymes, insulin and many of the hormones, albumin, fibrinogen, and many other components of the blood plasma.

The conjugated proteins represent a further step in structure. After a simple protein molecule has been built by the joining together of molecules of different amino acids, it may hook on to a pigment and form a conjugated protein such as the hemoglobin of the blood. Or, it may attach itself to a complicated chain of sugar molecules known as a polysaccharide and form a conjugated protein of another type, such as the mucin of saliva. Another possibility is the joining of a protein with a vitamin—the enzyme carboxylase is of this type. Finally, proteins may be linked with nucleic acids to form nucleoproteins—and here we reach the ultimate of giantism among molecules. For if a simple protein is pictured as a whale among the minnows, a nucleoprotein may be likened to a leviathan with form so tremendous that it might swallow the whale. Nucleic acid alone is a large structure—some of its



FORMATION OF CLUMPS may proceed on the basis postulated in the drawings on page 18. Antigen and antibody molecules are joined together until they form a visible precipitate. When an antibody lacks this precipitating power, it is probably unable to combine with more than one antigen.



FITTED GROUPS OF ATOMS are the basis for the specificity of antigen and antibody. In the center is *p*-azosuccinanilate ion group of a protein molecule. Around it is the complementary region of an antibody that specifically combines with it. Antigen and antibody are one Angstrom apart.

molecules contain 160,000 atoms—and when units of this size combine with units the size of proteins, the combination is truly enormous. Some of the viruses which Wendell M. Stanley isolated in his studies at the Rockefeller Institute were identified as nucleoproteins and had a molecular weight up to eight million times that of hydrogen. Such structures comprise nearly a million atoms.

IT is believed that both viruses and genes are nucleoproteins, while the antibodies are thought to be simple proteins consisting of chains of amino-acid residues folded together in a certain way. These folded chains of interlinked amino-acid residues are called polypeptides. According to Pauling's theory, countless numbers of them are afloat in the bloodstream; and whenever they encounter certain bacteria, viruses, or other foreign bodies in the blood, the mutual attractions between the two cause the chain to approach and attach itself to the invader. The action of the chemical bond thus causes the polypeptide chain to fold up and overlay a surface area of the microbe, forming a shield or encrustation which blocks the latter's activity

"The genes, we believe, exercise an overruling control on all these activities," said Beadle. "They do this, we think, by serving as the master patterns for the many proteins which function in the processes of life. Thus, there is probably a gene which serves as the template for the body's manufacture of insulin, another which provides the mold for pepsin, and so for albumin, fibrinogen, the polypeptide chain that forms antibodies, and all the rest.

"There are several thousand genes distributed among the 48 chromosomes of the human body cell, a number sufficient to provide templates for the thousands of big molecules required for health. Diabetes, on this theory, is a consequence of a missing or defective gene, leaving its victim unable to manufacture insulin. Similarly, the bleeders or hemophiliacs lack the normal gene for manufacturing a substance which is an essential component of the blood-clotting equipment.

"Our experiments with the bread mold, *Neurospora*, have demonstrated this genic control of the biochemical processes in numerous instances. We found, for example, that after exposure to ultraviolet radiation, *Neurospora* lost its ability to make certain vitamins. The genes which controlled this manufacture had been destroyed, and thereafter *Neurospora* languished unless these vitamins were supplied in its food. Similarly, Sterling Emerson of our laboratory found that a minute change in its genes caused the *Neurospora* to accept as food a compound that before the change had

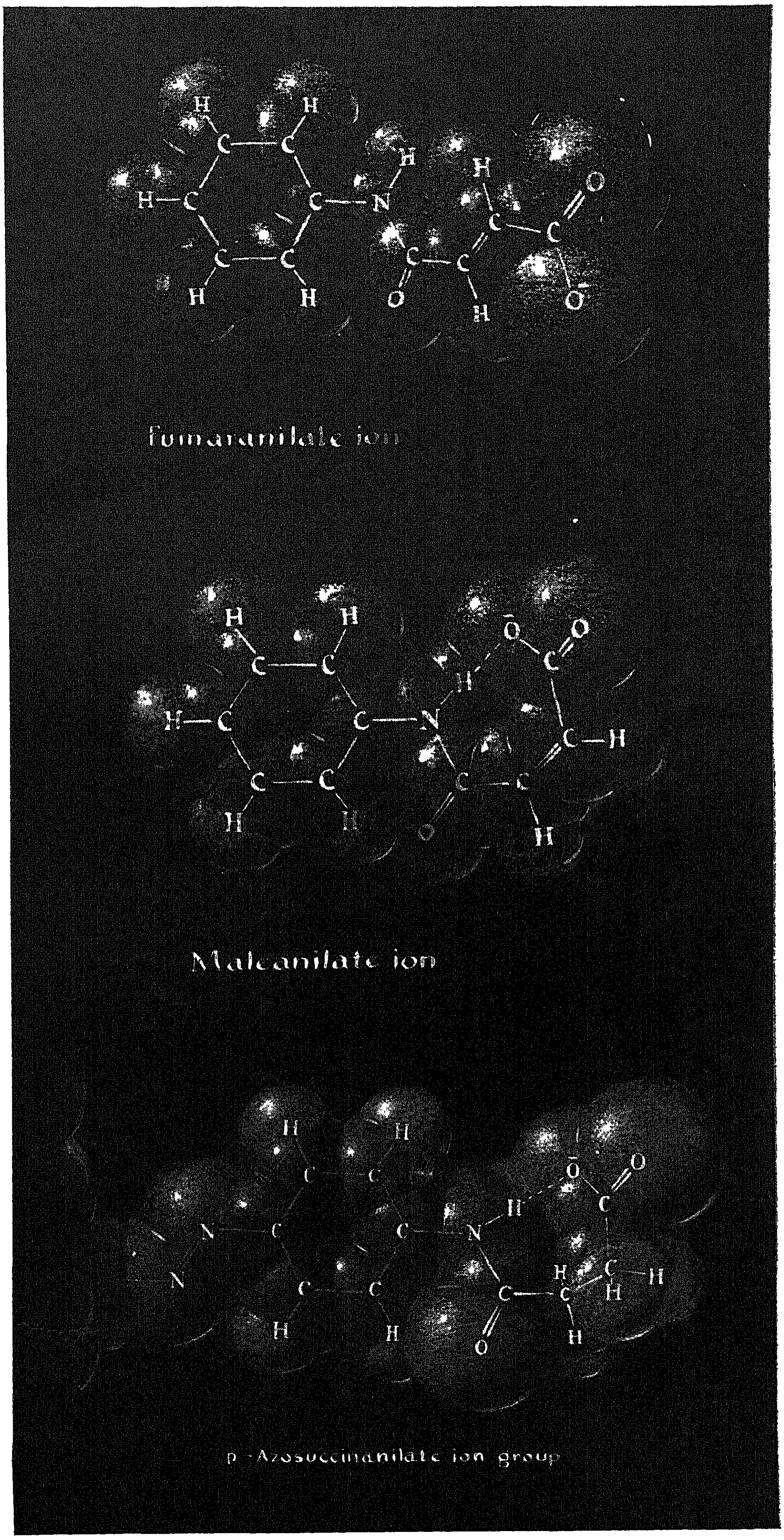
acted as a poison. Indeed, after mutation, the *Neurospora* would not grow unless fed a sulfonamide which previously had blocked growth and caused death."

As a step toward understanding the proteins, the chemists are working first on the amino acids, trying to map precisely the structure of these protein building blocks. Robert B. Corey spent a year and a half analyzing the configuration of glycine, the simplest of the amino acids. He bombarded it with X-rays, and measured the angles at which the rays bounded off the molecule. In this way he not only determined the position of each carbon atom, each oxygen and each hydrogen in the glycine, but actually measured the distances between the atoms. After completing this job, Corey went on to alanine, which is larger and more complicated. The experience he had gained on glycine stood him in good stead, and he required only a year to work out the exact pattern of alanine. He has now taken up a still more complicated amino acid, threonine. Step by step the group plans to move from the amino acids to more complicated structures, with the hope that eventually they may be able to dissect some of the proteins, perhaps even nucleoproteins, into their integral parts.

The strongest impression that one brings back from a visit to the Institute team is the magnitude of the task of analyzing these invisible molecules. Henry A. Rowland used to tell his students at Johns Hopkins University that the mercury atom must be at least as complicated as a grand piano. Following this analogy one might say that the biological molecule, such as a unit of insulin, for example, is probably as complicated as a symphony orchestra. The grand piano of mercury has now been completely mapped in terms of electrons, protons and neutrons, and the physicists are even able by the bombardment technique to make mercury from other elements. But the full symphony of insulin remains a chemical enigma. No one yet has analyzed it, and of course no synthesis of insulin has been achieved.

Fortunately medical men are able to use biologically-active molecules without knowing very much about them, but they crave the control of processes and results which fundamental knowledge would give. Along this road, the scientists believe, lies the unmasking of stubborn mysteries: the elucidation of cancer, of aging, of the divine spark itself. The search for fundamental knowledge thus becomes the most practical of all biochemical quests.

George W. Gray is author of Cosmic Rays, *which appeared in the March issue of this magazine.*



REMARKABLE SPECIFICITY of antibodies was demonstrated by experiment involving three very similar atomic structures. Maleanilate ion was found to inhibit antibody specific for *p*-azosuccinanilate ion group. Fumaranilate ion did not inhibit antibody, presumably because it did not fit.

THE THEORY OF GAMES

From it is being forged a new tool for the analysis of social and economic behavior. The new approach already has shown its superiority to classical economic theory

by Oskar Morgenstern

THE analogy between games of strategy and economic and social behavior is so obvious that it finds wide expression in the thinking and even the language of business and politics. Phrases such as "a political deal" and "playing the stock market" are familiar reflections of this. The connection between games and these other activities is more than superficial. When they are examined by the methods of modern mathematics, it becomes evident that many of the forms of economic and social behavior are strictly identical with—not merely analogous to—games of strategy. Thus the mathematical study of games offers the possibility of new insights and precision in the study of economics.

The theory of probability arose from a study of lowly games of chance and from the desire of professional gamblers to find ways of taking advantage of the odds. Far more difficult problems are presented by games of strategy such as poker, bridge and chess. In these games, where the outcome no longer depends on chance alone but also on the acts of other players and on their expectations of one's own present and future acts, a player must choose among relatively complex strategies. Mathematically, these problems remained not only unsolved, but even untouched.

Gottfried Wilhelm Leibnitz, the German philosopher and mathematician, seems to have recognized that a study of games of strategy would form the basis of a theory of society. On the other hand, many efforts along quite different lines were made by philosophers and economists to provide a theory for "rational behavior" for individuals, business corporations, or even for entire communities.

Such a theory must be quantitative, which means that it must ultimately assume a mathematical character. A theory of games fulfilling these requirements would take into account that participants in a game vary in information and intelligence, that they have various expectations about the other players' behavior, and that different paths of reaching their goal may be open to them. The theory must also allow for the fact that the position of a player (or, equivalently, of an economic individual or a firm) is often adversely affected if his opponent finds out his intentions. The player has to take steps to protect himself against this contingency, and the theory must indicate how he should proceed most efficiently—and what his countermeasures would mean to the other players.

Why should such a theory be of interest to the sociologist and, in particular, to the economist? Does not the economics of today have an adequate model in mechanics, with its notions of forces, of equilibrium and stability? Physics is, indeed, at the bottom of current efforts to provide a statement of rational economic behavior, whether it is mathematically formulated or not. But many important situations that arise at all levels in economics find no counterpart whatever in physics.

A typical example is the fixing of wage rates between workers and employers when both groups have found it to their advantage to combine into unions and associations. Current economics cannot tell us, except in a general manner, under what circumstances such combinations will arise, who will profit, and by how much. The two groups have opposing interests, but do not have separate means to pursue their contrary aims. They must finally come to some agreement, which may turn out to be more advantageous to one side than to the other. In settling their differences they will feint, bluff, use persuasion, they will try to discover each other's strategies and prevent discovery of their own. Under such circumstances a theory of rational behavior will have to tell a participant how much a given effort will be worth in view of the obstacles encountered, the obstacles being the behavior of his opponents and the influence of the chance factor.

Monopoly and monopolistic market forms—that is, trading among only a few individuals or firms on one side of the market at least—are characteristic of all social economies. They involve serious feuds and fights, a very different picture from the general, "free" competition with which classical economic theory usually deals. On the orthodox theory, the individual is supposed to face prices and other conditions that are fixed, and is supposed to be in a position to control all the variables, so that his profit or utility depends only on his own actions. Actually, however, when there are only a few individuals, or many individuals organized into a few combinations, the outcome never depends on the actions of the individual alone. No single person has control of all the variables, but only of a few.

The case of an individual acting in strict isolation can be described mathematically as a simple maximum problem—that is, finding the behavior formula that will yield the maximum value or return. The cases involving combinations are of an entirely different mathematical and logical structure. Indeed, they present a peculiar mixture of maximum problems, creating a profound mathematical question for which there is no parallel in physical science or even in classical mathematics.

Yet this is the level at which the problem of economic behavior needs to be attacked. Clearly it is far more realistic to investigate from the outset the nature of the all-pervading struggles and fights in economic and social life, rather than to deal with an essentially artificial, atomistic, "free" competition where men are supposed to act like automatons confronted by rigidly given conditions.

THE theory of games defines the solution of each game of strategy as the distribution or distributions of payments to be made by every player as a function of all other individuals' behavior. The solution thus has to tell each player, striving for his maximum advantage, how to behave in all conceivable circumstances, allowing for all and any behavior of all the other players. Obviously this concept of a solution is very comprehensive, and finding such a solution for each type of game, as well as computing it numerically for each particular instance, poses enormous mathematical difficulties. The theory makes important use of mathematical logic, as well as

combinatorics (the study of possible ways of combining and ordering objects) and set theory (the techniques for dealing with any collection of objects which have one or more exactly specified properties in common). This domain of modern mathematics is one of exceptional rigor. But it is believed that great mathematical discoveries are required to make a break-through into the field of social phenomena.

A single individual, playing alone, faces the simplest maximum problem; his best strategy is the one that brings him the predetermined maximum gain. Consider a two-person game: Each player wishes to win a maximum, but he can do this only at the expense of the other. This situation results in a zero-sum game, since the sum of one player's gains and the other's losses (a negative number) is zero. One player has to design a strategy that will assure him of the maximum advantage. But the same is true of the other, who naturally wishes to minimize the first player's gain, thereby maximizing his own. This clear-cut opposition of interest introduces an entirely new concept, the so-called "minimax" problem

SOME games have an optimal "pure" strategy. In other words, there is a sequence of moves such that the player using it will have the safest strategy possible, whatever his opponent does. His position will not deteriorate even if his strategy is found out. In such "strictly determined" games, every move—and hence every position resulting from a series of moves— is out in the open. Both players have complete information. The mathematical expression of this condition is that the function describing the outcome of a game has a "saddle point." This mathematical term is based on an analogy with the shape of a saddle, which can be regarded as the intersection of two curves at a single point. One curve in a saddle is the one in which the rider sits; the other is the one that fits over the horse's back and slopes down over its sides. The seat of the saddle represents the "maximum" curve, and its low point is the "maximin." The curve that straddles the horse's back is the "minimum" curve, and its high point is the "minimax" The point at which the two curves meet at the center of the saddle is the "saddle point." In the theory of games, the somewhat more special saddle point is the intersection of two particular strategies.

The mathematical values of the strategies involved in a hypothetical game of this kind are represented in the diagram on this page. This shows a simple game between two players, A and B, each of whom has available three possible strategies. There are nine possible combinations of moves by A and B. The numbers in the boxes represent A's gains or losses for all combined strategies and, since this is a zero-sum game, their negatives represent B's losses or gains. A's minimax strategy is A-2, because if he follows that sequence of moves, he is sure to win at least two units no matter what B does. Similarly, B's minimax strategy is B-1, because then he cannot possibly lose more than two units whatever A's plan of action. If a spy informed A that B was planning to use B-1, A could make no profit from that information. The point where the A-2 row intersects the B-1 column is the saddle point for this game.

It may seem that B has no business playing such a game, since he must lose two units even with his best strategy, and any other strategy exposes him to even heavier loss. At best he can win only a single unit, and then only if A makes a mistake. Yet all strictly determined games are of this nature A simple example is ticktacktoe. In perfectly played ticktacktoe every game would result in a tie. A more complex example is chess, which has a saddle point and a pure strategy. Chess is exciting because the number of possible moves and positions is so great that the finding of that strategy is beyond the powers of even the best calculating machines.

A \ B	B-1	B-2	B-3
A-1	2	1	4
A-2	2	3	2
A-3	2	-1	1

GAME OF STRATEGY between two players, each with three possible strategies, has nine possible results. Numbers in boxes represent A's gains or losses for each combination of plays by both players.

Other two-person, zero-sum games, however, have no single best possible strategy. This group includes games ranging from matching pennies to bridge and poker—and most military situations. These games, in which it would be disastrous if a player's strategy were discovered by his opponent, are not strictly determined. The player's principal concern is to protect his strategy from discovery. Do safe and good strategies exist for "not strictly determined" games, so that their choice would make the games again strictly determined? Can a player in such a game find strategies other than "pure" strategies which would make his behavior completely "rational"? Mathematically speaking, does a saddle point always exist?

It does, and the proof was originally established in 1927 by the mathematician John von Neumann, the originator of the theory of games, now at the Institute for Advanced Study in Princeton He used various basic tools of modern mathematics, including the so-called fixed-point theorem of the Dutch mathematician L. E. J. Brouwer. Von Neumann proved, by a complex but rigorous application of this theorem to the theory of games, that there is a single "stable" or rational course of action that represents the best strategy or saddle point even in not strictly determined games.

This principle can also be demonstrated in practical terms. Observation shows that in games where the discovery of a player's plan of action would have dangerous consequences, he can protect himself by avoiding the consistent use of a pure strategy and choosing it with a certain probability only This substitution of a statistical strategy makes discovery by the opponent impossible. Since the player's chief aim must be to prevent any leakage of information from himself to the other player, the best way to accomplish this is not to have the information oneself. Thus, instead of choosing a precise course of action, the various possible alternatives are considered with different probabilities.

It is in the nature of probability that individual events cannot be predicted, so that the strategy actually used will remain a secret up to the decisive moment, even to the player himself, and necessarily to his opponent as well. This type of indecision is a well-known empirical fact. Wherever there is an advantage in not having one's intentions found out—obviously a very common occurrence—people will be evasive, try to create uncertainty in the minds of others, produce doubts, and at the same time try to pierce the veil of secrecy thrown over their opponents' operations.

The example *par excellence* is poker. In a much simpler form, this type of behavior is illustrated in the game of matching pennies Here the best strategy is to show heads or tails at random, taking care only to play each half the time. Since the same strategy is available to the opponent, both players will break even if they play long enough and both know this principle. The calculation of the best strategy grows in difficulty as the number of possible moves increases: *e.g.*, in the Italian game called morra, in which each player shows one, two or three fingers and simultaneously calls out his guess as to the sum of fingers shown by himself and his opponent, a player has nine possible strategies. His safest course is to guess a total of four fingers every time, and to vary his own moves so that out of every 12 games he shows one finger five times, two fingers four times and three fingers three times. If he plays according to this mixture of

strategies, he will at least break even, no matter what his opponent does

LET us apply these principles to a simple economic problem Suppose that two manufacturers are competing for a given consumer market, and that each is considering three different sales strategies. The matrix on this page specifies the possible values of the respective strategies to manufacturer A This situation does not have a single best strategy If A chooses strategy A-1, B can limit his profit to one unit by using strategy B-2 or B-3, if A chooses strategy A-2 or A-3, B can deprive him of any profit by choosing strategy B-1 Thus each manufacturer stands to lose if he concentrates on a single sales technique and his rival discovers his plan. Analysis shows that A will lose unless he uses a combination of A-1, A-2 and A-3, each a third of the time. On the other hand, if manufacturer B fails to employ his best mixed strategy—B-1 a ninth of the time, B-2 two ninths of the time, and B-3 two thirds of the time—his competitor will gain. These mixed strategies are the safest strategies. They should be used whenever each manufacturer does not know what the other will do.

An example which illustrates in statistical terms many of the conflicts of choices involved in everyday life is the famous story of Sherlock Holmes' pursuit by his archenemy, Professor Moriarty, in Conan Doyle's story, "The Final Problem." Holmes has planned to take a train from London to Dover and thence make his escape to the Continent. Just as the Dover train is pulling out of Victoria Station, Moriarty rushes on the platform and the two men see each other. Moriarty is left at the station. He charters a special train to continue the chase. The detective is faced with the problem of outguessing his pursuer Should he get off at Canterbury—the only intermediate stop—or go all the way to Dover? And what should Moriarty do? In effect, this situation can be treated as a rather unusual version of matching pennies—a "match" occurring if the two men decide to go to the same place and meet there. It is assumed that such a meeting would mean the death of Sherlock Holmes, therefore it has an arbitrarily assigned value of 100 to Moriarty If Holmes goes to Dover and makes his way to the Continent, it is obviously a defeat for the professor, but—also obviously—not as great a defeat as death would be for the detective. Hence, a value of minus 50 to Moriarty is given to this eventuality. Finally, if Holmes leaves the train at Canterbury and Moriarty goes on to Dover, the chase is not over and the temporary outcome can be considered a draw. According to the theory of games, the odds are 60 to 40 in favor of the professor.

In the story, of course, this game is played only once; Sherlock Holmes, deducing that Moriarty will go to Dover, gets off at Canterbury and watches triumphantly as the professor's pursuing train speeds past the intermediate station. If the game were continued, however, Holmes' look of triumph would hardly be justified. On the assumption that Moriarty persisted in the chase, calculations indicate that the great detective was actually as good as 40 per cent dead when his train left Victoria Station!

The theory of games has already been applied to a number of practical problems Situations similar to that of Holmes are being analyzed in that branch of operational research which deals with military tactics, the possible courses of action being various dispositions of troops or combinations of measures and countermeasures The handling of the more complex situations that exist in economics is expected to require the aid of calculating machines. For example, two competing automobile manufacturers may each have a large number of strategies involving the choice of various body designs, the addition of new accessories, the best times to announce new models

A \ B	B-1	B-2	B-3
A-1	4	1	1
A-2	0	3	1
A-3	0	0	2

BUSINESS RIVALRY between two firms with three strategies each again diagrams A's possible gains. No single strategy is best if the opponent discovers it; hence the rivals must use a mixture of all three.

and price changes, and so on. It has been estimated that the calculations for a game in which one manufacturer had 100 possible strategies and his competitor had 200 (a not uncommon situation) would take about a year on an electronic computer.

If we now make the transition to games involving three or more persons, a fundamentally new phenomenon emerges—namely, the tendency among some players to combine against others, or equivalently in markets to form trade unions, cartels and trusts Such coalitions will be successful only if they offer the individual members more than they could get acting separately. Games where that is the case are called essential. Coalitions will then oppose each other in the manner of individual players in a two-person game. A coalition will have a value for the players who form it, and they may therefore require payments or "compensations" from newcomers who want to enter the coalition and share in its proceeds As a rule a great deal of bargaining will precede the determination of the system of distribution of gains or profits among the members of the coalition.

Basically, the formation of a coalition expresses the fundamental tendency toward monopoly, which is thus found to be deeply characteristic of social and economic life. Indeed, Adam Smith already had noted the tendency of businessmen to "conspire" against the common welfare, as he stated it, by getting together into groups for better exploitation. Important chapters of American economic history deal with the efforts of government to break conspiracies of various kinds in order to limit the power of trusts and other amalgamations. When these are broken—if at all—they tend to arise again, so a continuous watchfulness is necessary.

The powerful forces working toward monopoly ought therefore to be at the very center of economic studies. They should replace the preoccupation with a nonexistent pure or free competition where nobody has any perceptible influence on anything, and where all data are assumed to be immutably given. Since this is the imaginary setup from which current economic theory starts, it encounters insuperable difficulties when it enters the realm of monopolistic competition. It is not surprising, therefore, that classical economics has failed to yield a general theory that embraces all economic situations.

THE approach to the coalition problem in the theory of games can be shown by a three-person situation in which it is assumed that a player can achieve a gain in any given play only if he joins with one other player. The gains and losses that would result for the individual players in the case of each possible coalition are shown in the diagram on page 25 Thus if A and B form a coalition, each gains a half unit and C loses one unit. What keeps the players in the game is that they all stand a chance of profit, each player's problem is to succeed in forming a coalition with one of the other two on any given deal. This simplified situation illustrates in essence much of the conflict that occurs in modern economic life.

Now the important characteristic of this type of game is that there is no single "best" solution for any individual player. A, for example, can gain as much by forming a coalition with C as with B. Therefore all three of the possible distributions of payments, taken together, must be viewed as the solution of this three-person game.

There are, of course, many other distribution schemes that might be con-

sidered by the players For example, one of the partners in a coalition could make a deal with the third player whereby both improved their positions (the third player reducing his losses) at the expense of the other partner What is to prevent the participants in the game from considering all these other possibilities?

The question can be answered by introducing the concept of "domination." In mathematical terminology the various possible schemes for distribution of payments are called "imputations." One imputation is said to dominate another if it is clearly more advantageous to all the players in a given coalition. It is found, as shown in the three-person game described above, that the imputations belonging to a solution do not dominate each other. in this case all three imputations have an equal chance of being chosen, none is most advantageous to the players in each coalition. While it is extremely difficult to prove mathematically that such a solution would exist for every game with arbitrarily many players, the principle can be expected to hold true.

Now it is also found that while the imputations belonging to the solution do not dominate each other, individually they are not free from domination by imputations outside the solution. In other words, there are always outside schemes from which some of the players could profit. But any and every imputation outside the solution is dominated by one belonging to the solution, so that it will be rejected as too risky. It will be considered unsafe not to conform to the accepted standard of behavior, and only one of the imputations which are part of the solution will materialize.

These examples give an idea of the great complexity of social and economic organization. In this realm "stability" is far more involved than it is in the physical sciences, where a solution is usually given by a number or a set of numbers. In essential games, in economics and in warfare, there is instead a set of alternatives, none of which is clearly better than another or all others. One imputation in a set is not more stable than any other, because every one may be threatened by one outside the solution. But each has a certain stability because it is protected by other potential imputations in the solution against upsets from outside. Collectively they eliminate the danger of revolutions. The balance is most delicate, however, and it becomes more sensitive as the number of players increases. These higher-order games may have many solutions instead of a single one, and while there is no conflict within an individual solution, the various solutions or standards of behavior may well conflict with one another.

This multiplicity of solutions may be interpreted as a mathematical formulation of the undisputed fact that on the same physical background of economic and social culture utterly different types of society can be established. Within each society, in turn, there is possible considerable variation in the distribution of income, privileges and other advantages—which corresponds to the multiplicity of imputations or distribution schemes in a single solution in a game.

The theory also yields insight into even more delicate social phenomena. Although it assumes that every player has full information, discrimination may exist: two players may make a third player "tabu," assigning him a fixed payment and excluding him from all negotiations and coalitions. Yet this arrangement need not lead to complete exploitation of the third player. In practical economic life, for example, cartels do not annihilate all outside firms, although it would not be a technically difficult operation. Rather, in deference to socially accepted standards of behavior they allow certain outsiders a share in the industry, so as not to attract undue attention—and to be able to point out to the government and the public that "competition" exists in the particular industry.

INDIVIDUAL PLAYERS / COALITIONS	A	B	C
A,B	½	½	-1
A,C	½	-1	½
B,C	-1	½	½

COALITION GAME with three players produces still another matrix. Here gains or losses to players resulting from various possible coalitions are shown in vertical columns. Player must form partnership to win.

It is surprising and extremely significant that, although the theory of games was developed without any specific consideration of such situations, the fact that they exist was derived from general theorems by purely mathematical methods. Furthermore, the theory shows—again purely mathematically—that certain privileges, even if anchored in the rules of a game (or of a society), cannot always be maintained by the privileged if they come into conflict with the accepted standard of behavior. A privileged person or group may have to give up his entire "bonus" in order to survive economically.

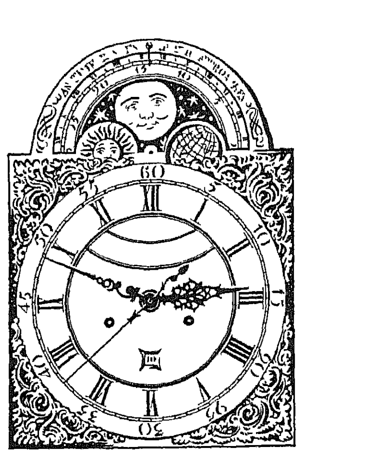
These and many other implications can be derived from the study of simple three-person games. Games of more than three players provide further interesting insights—but at the price of great and, in many cases, still insuperable mathematical difficulties. The almost unimaginable complexity involved may be illustrated by poker, the game which, above all others, furnishes a model for economic and social situations. The subtleties of poker and the countless number of available strategies—*e.g.*, the technique of purposely being caught bluffing now and then so that future bluffs may be successful—prevent the thorough analysis that would be necessary to throw light on corresponding problems in practical everyday affairs. The matrix of possible strategies for poker is so large that it has not even been calculated, much less drawn. Consider a radically simplified version of the game which assumes a deck of only three cards, a one-card, no-draw hand, only two players, three bids between them (the first player gets two, the second one), and no overbetting. Even this watered-down version of poker involves a matrix of 1,728 boxes, and computing a single best possible strategy for each player to an accuracy of about 10 per cent might require almost two billion multiplications and additions.

BUT even with its present limitations the theory of games has made it possible to analyze problems beyond the scope of previous economic theory. Besides those already indicated, the problems now being explored include the application of the mathematics for a game involving seven persons to the best location of plants in a particular industry, the relation between labor unions and management, the nature of monopoly.

The initial problem in the theory of games was to give precision to the notion of "rational behavior." Qualitative or philosophical arguments have led nowhere, the new quantitative approach may point in the right direction. Applications are still limited, but the approach is in the scientific tradition of proceeding step by step, instead of attempting to include all phenomena in a great general solution. We all hope eventually to discover truly scientific theories that will tell us exactly how to stabilize employment, increase national income and distribute it adequately. But we must first obtain precision and mastery in a limited field, and then proceed to increasingly greater problems. There are no short cuts in economics.

Oskar Morgenstern is professor of economics at Princeton University and coauthor with John von Neumann of Theory of Games and Economic Behavior.

SCIENCE AND THE



Atomic Energy

THE Atomic Energy Commission is building a 400,000-acre field station to study the "breeding" of nuclear fuels and the design of nuclear piles for ship propulsion and the generation of electricity. Located in the sparsely settled Snake River plains region of southern Idaho, the station will cover an area nearly as large as the AEC's plutonium production center in Hanford, Wash. Most of the site, which includes the idle Arco Naval Proving Ground, is already owned by the Federal Government.

Magnetic Moment

A NEW, highly precise value for one of the fundamental constants of nuclear physics—the magnetic moment of the proton—has been determined by H. A. Thomas, R. L. Driscoll and J. A. Hipple of the National Bureau of Standards. Protons behave like tiny magnets, interacting with magnetic fields, and the magnetic moment is a measure of this interaction. The Bureau has been able to calculate the absolute value of the moment directly for the first time. It is 1.41×10^{23} ergs per gauss.

The determination will aid in calculating other nuclear constants, in designing research equipment and in measuring magnetic fields. In fact, the new value has already been used to compute the most precise figure yet attained for another important constant, the ratio of the electron's charge to its mass. e/m. The new ratio is 1.7588×10^7 electromotive units per gram.

Stalin Prizes

FURTHER evidence has come from the Soviet Union that T. D. Lysenko, proponent of the much-publicized and controversial anti-Mendelian theory of genetics, is a scientist not without honor in his own country. The Russian agronomist has just received the top Stalin Prize in biology, amounting to 200,000 rubles (about $40,000). This honor is the U.S.S.R.'s equivalent of the Nobel prize, and is one of a series of awards given annually for outstanding work in the arts and sciences. Although more than one first prize may be given in any branch of science, only Lysenko received the highest honor in his field.

A large proportion of the other Stalin awards went to atomic scientists. Physicists won three of the 13 first prizes and three of the 100,000-ruble second prizes. Most of them were cited for achievements in nuclear research. The three first-prize winners in physics were Sergei Vernov, chief of the Physical Institute of the Academy of Sciences (upper-atmosphere and cosmic-ray studies); Giorgi Latishev, head of the Leningrad Physical Technical Institute (experimental research in the physics of the atomic nucleus); Mikhail Lavrentiev (research in hydrodynamics).

Several prizes were also awarded in medicine, engineering and agriculture. These included the only woman among the first-prize winners, Senia Bakhtadze, who was cited for developing two new types of tea.

Degrees C.

SCIENTISTS representing 28 nations have voted to discard the traditional designation "degrees Centigrade" for metric temperature readings and to use "degrees Celsius" instead. The recommendation was made at the International Conference on Weights and Measures, holding its first meeting since 1933 in Paris. The renaming is in honor of the 18th-century Swedish astronomer, Anders Celsius. It was suggested to end confusion arising from the French practice of using the term "Centesimal" as well as "Centigrade." Although the decision was unanimous, few of the delegates expect a rapid change-over from the old to the new name.

The Conference also voted to revise one of the six fundamental points used to fix the International Temperature Scale. This is the melting point of silver, changed from 960.5 to 960.8 degrees Celsius. The other fundamental points are: boiling point of oxygen, —182.97 degrees C.; freezing point of water, 0 degrees; boiling point of water, 100 degrees, boiling point of sulfur, 444.60 degrees; and melting point of gold, 1,063 degrees. The new silver point, as well as several revisions in the procedures for determining intermediate temperatures, will become standard throughout the scientific world.

Hoover Commission

CREATION of a National Science Foundation and a strong interdepartmental committee to coordinate Federal research are urged in the latest report of the Hoover Commission. The Commission does not mention any specific science-foundation bill, several being currently before Congress. One, sponsored jointly by three Democratic and three Republican Senators, is expected to pass during the present session. The Hoover Commission did not assign a special "task force" to investigate Federal science activities; instead, it endorsed most of the conclusions in the recent report of the President's Scientific Research Board.

The Hoover report declares that the Interdepartmental Committee on Scientific Research and Development (set up by Presidential order more than a year ago to coordinate Federal research activities) has not functioned effectively because it lacks a full-time staff. The Hoover Commission recommends that the Committee be given sufficient personnel and greater authority. It also urges the establishment of general-research policy staffs in all Federal agencies with extensive research programs. The Department of Agriculture, the U. S. Public Health Service and the armed forces already have such units.

Robot Reader

MANY scientific discoveries—the most notable being Gregor Mendel's revolutionary contribution to genetics—have remained unknown for decades because they were buried in obscure technical journals and inadequately indexed. The problem, which often results in wasteful duplication of research, is becoming increasingly serious with the rapidly growing accumulation of scientific literature. Today the task of searching for references to a particular problem may involve hundreds of books and periodicals, under scores of subject headings.

An "electronic selector" which may help break this bottleneck in science and reduce the searching process from weeks to minutes is to be placed in service this month in the Department of Agriculture library. The machine scans 75,000 microfilmed documents a minute, sorts out those dealing with the desired subject and reproduces them either on 35-millimeter film or on V-mail paper for delivery to the reader.

The selector is an offspring of "memex," a device proposed three years ago by Vannevar Bush. Memex was to put printed matter on microfilm with coded index dots at the edge of each frame of film. The dots would be read at very high speeds by a battery of photoelectric cells, which would select what was wanted. Bush's machine

CITIZEN

seemed impractical. It required a separate photoelectric cell for each of the 270 positions where a code dot could be placed—a prohibitively expensive arrangement. But Ralph Shaw, Department of Agriculture librarian, devised a method for reducing the cells to six.

Eventual commercial versions of the Shaw machine will cost roughly $15,000 each. They will scan 120,000 or more documents a minute for several subjects at once Searches through collections as voluminous as the Patent Office file will take hours instead of weeks.

Corn Ancestor

TWO young Harvard graduate students have found an important clue to the origin of corn, for four centuries a leading botanical puzzle. While searching for remains of early American man in a cave in the upper Gila River area of New Mexico, Herbert Dick and C. Earle Smith uncovered a store of prehistoric corn. Their find includes 766 cobs and fragments from hundreds of other ears. These were located in six underground layers, the oldest dating back at least 4,000 years. The dry New Mexico climate has preserved hundreds of cobs well enough to permit detailed botanical study.

The corn had been cultivated but, unlike modern corn, could have grown wild The cobs were two inches long and about as thick as a wax crayon. Instead of a husk encasing the entire ear, each kernel had a covering of chaff. The kernels were a third the size of those of ordinary sweet corn, and were as hard as popcorn. The most important conclusion from the find is that corn did not evolve from the related Central and South American grass known as teosinte, as previously believed. It must have come from another species.

Rejuvenating Light

ALL studies of the lethal effect of ultraviolet light on bacteria and other simple forms of life, as well as genetic research on ultraviolet-induced mutations, may have to be re-examined to take account of a widely ignored effect which may modify or invalidate many findings. According to Albert Kelner of the Cold Spring Harbor Biological Laboratory, visible light induces the recovery of microorganisms that have apparently been killed by ultraviolet rays.

Kelner was studying the effect of cold on the recovery of a particular strain of irradiated *Streptomyces griseus*, a strain which is closely related to the molds from which streptomycin is obtained. A

factor other than temperature was involved, however, since some mold cultures showed excellent recovery at 35 degrees C. while others showed none at all. Then Kelner found that some of the recuperating cultures happened to have been placed near a window, and suspected the influence of sunlight This possibility was confirmed in controlled experiments which showed that radiation at the wavelengths of visible light could produce a 400,000-fold increase in the number of molds surviving supposedly lethal ultraviolet exposures.

The findings may have an important bearing on virus studies such as those conducted at Indiana University, Washington University and other institutions. In this work two strains of the bacteria-infecting viruses known as bacteriophage were "killed" with ultraviolet rays, and then placed in a solution containing their bacterial prey. When the viruses multiplied and successfully destroyed the bacteria, it was believed that the two strains had combined their undamaged parts to form a new strain. The visible-light effect, however, might have produced similar results.

Radiation and Genes

ACCORDING to Robley D. Evans of the Massachusetts Institute of Technology, there is little danger of genetic mutations from exposure to moderate doses of X-rays or atomic radiations. Moreover, natural radiation from cosmic rays and radioactive minerals is insufficient to account for the mutations observed in nature.

Standard U. S. practice is to limit radiation workers to a maximum exposure of .1 roentgen a day. This amounts to about 25 roentgens for a year of five-day weeks, or 250 roentgens in a decade, and Evans estimates that the latter dose would increase the number of spontaneous mutations by only 1.5 per cent. Workers at Hanford, Oak Ridge and other atomic-energy plants would have to stay on the job continuously for at least 125 years to accumulate a radiation dose of that size, for the average exposure in such plants is 005 roentgen a day, less than two roentgens a year.

Actually, two roentgens a year may not produce any genetic changes. In recent experiments at M.I.T., Evans reports, doses of 2.5 roentgens a day failed to increase the mutation rate of fruit flies, which are probably more susceptible to radiation-induced mutations than man.

Evans has found no evidence to support the idea that cosmic rays and other natural radiations are the chief factors responsible for the spontaneous mutations underlying evolutionary change. Exposure to natural radioactivity amounts to only .003 roentgen a day, a feeble dosage that could account for only one per cent of the number of mutations that is known to occur spontaneously per generation in man and other organisms.

Mouse Cancer Virus

THE milk-factor virus of mouse breast cancer had been isolated by a team of researchers at Columbia University's newly established Institute of Cancer Research The virus has been the object of an intensive search since 1936, when J. J. Bittner showed that it is responsible for the fact that mouse mammary cancer is transmitted to offspring through the mother's milk. The isolation was accomplished by Samuel Graff, biochemist, Dan H. Moore, biophysicist; Henry T. Randall and Cushman D. Haagensen, surgeons; and Wendell M. Stanley, formerly of the Rockefeller Institute.

The virus, which may be a nucleoprotein, was obtained from the milk of mice with a high inbred incidence of cancer, as well as from low-cancer animals foster-nursed by high-cancer mothers. As little as .008 gamma—less than a hundred millionth of a gram—causes mammary cancer. The disease may be induced by either mouth feeding or injection of the virus, in either males or females. However, the incidence of cancer is much less if the mouse is more than two weeks old at the time of inoculation.

Child Care

A COMPREHENSIVE survey by the American Academy of Pediatrics reveals that there are not enough doctors in the U. S. to provide adequate medical care for the nation's 36 million children. The survey took three years to complete and cost $1 million. Information was obtained from doctors, dentists and other health personnel in practically all of the nation's 3,071 counties. The situation is particularly bad among the 13 million children who live in rural areas.

The Academy found pediatricians overwhelmingly concentrated in urban areas, three quarters of them practicing in cities of 50,000 or more persons. The wide geographical variation in facilities for child care is illustrated by an urbanized state like Massachusetts, which has one pediatrician for every 3,000 children, while Mississippi has but one for every 35,000. Most children, especially in rural areas, receive care from general practitioners only. Half of the latter have had virtually no pediatric training and must send children to hospitals, a third of which are inadequately equipped.

The distribution of pediatricians is reflected in infant mortality rates. Counties with inadequate hospital and medical facilities have infant death rates five times as high as the best-equipped counties. In one state, the child death rate is higher than the national average a generation ago. Although the over-all child death rate last year was the lowest in American history, three babies die annually for every two American soldiers killed in action during each year of the war.

Hetrazan

HETRAZAN diethylcarbamazine, a drug developed by the American Cyanamid Company, may become the most effective means yet found for controlling filariasis, the mosquito-borne tropical disease which gives rise to elephantiasis. In three years of tests in the West Indies, Central America, India, Africa and the South Pacific, hetrazan has shown its ability to kill not only microfilariae, the embryo parasites, but also the adult worm.

In one recently reported study, 13 of 23 Puerto Rican patients who had received doses of the new drug were still free of parasites a year and a quarter after the treatment had been completed. The other 10 were probably given too small doses. Even when hetrazan does not cure, it may halt the spread of the parasite. among the 10 patients not cured, the number of microfilariae in the blood was reduced to a point below the level necessary to infect mosquitoes and thus spread the disease.

Hetrazan is closely related to certain metal-containing organic drugs which have been used for years in treating filariasis. Chemists succeeded in eliminating the metallic ingredients, thereby reducing the drugs' high toxicity.

Alcoholism Drug

TWO Danish physicians have made preliminary tests with a drug called antabus that may be helpful in combatting alcoholism. Antabus (tetraethylthiuram disulfide) is already being used in Scandinavia, and clinical trials are also under way in the U. S.

When a drinker patient who has previously been given a dose of antabus drinks more than a certain small amount (which varies with the patient's tolerance), he immediately experiences a series of exceedingly unpleasant reactions. His face and neck become purple-red and hot from dilation of the blood vessels in the skin. He is intensely nauseated, and develops a severe headache and choking sensation. This is followed by a premature hang-over which, according to the physicians responsible for the treatment, is "difficult to describe . . . but highly disagreeable." He recovers after a few hours of sleep, with considerably subdued desire to drink.

The drug acts by interfering, in an as yet unexplained manner, with the normal mechanism for oxidation of alcohol. The alcohol is oxidized to acetaldehyde, a compound which is usually found in freshly distilled spirits and is responsible for many of the unpleasant effects of "green" whiskeys. The discouraging reactions produced by anta-

bus result from acetaldehyde intoxication

Antabus is not in itself a cure for alcoholism. It has to be taken daily as long as there is any danger of a relapse, and it must be combined with intensive psychiatric treatment But the doctors who developed it, Erik Jacobsen and O. Martensen-Larsen, claim excellent results when patients can be persuaded to take the drug regularly.

Report from Los Alamos

RESEARCH looking toward release of atomic energy by reactions among light elements is under way at the Los Alamos laboratory. This is disclosed in the first systematic published account of the bomb laboratory and its activities, appearing in the *Bulletin of the Atomic Scientists* and prepared by J H Manley, technical associate director of the laboratory.

Nuclear energy is released by either of two processes, only one of which has been achieved in the laboratory—the familiar fission of heavy elements like uranium 235 or plutonium. The other is the fusion of light elements, an example, although probably not one of the reactions actually being studied, is the transformation of four hydrogen nuclei into a helium nucleus. The small amount of mass destroyed in the latter process furnishes the energy of the sun. Fusion takes place only at stellar temperatures, but is potentially a much larger source of energy than fission.

Dr. Manley gave no details of the Los Alamos studies of the fusion reaction. But he pointed out that light-element reactions are of interest not only because nuclear energy is released. Detailed knowledge of these reactions may contribute fundamentally to the development of nuclear physics.

Conservation

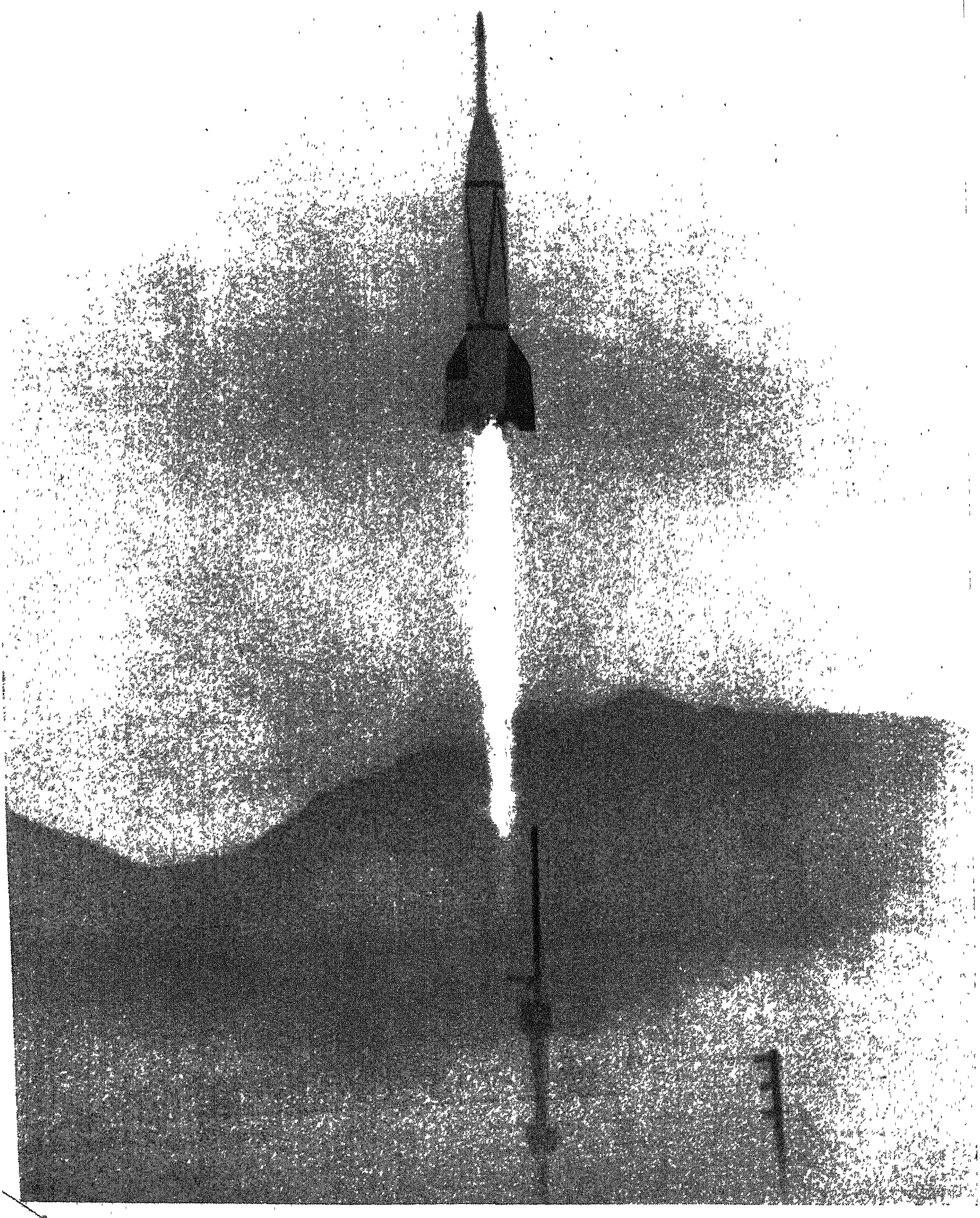
CONSERVATION and development of the world's resources will be discussed at a United Nations Scientific Conference on the Conservation and Utilization of Resources, which will be held at Lake Success, N. Y. from August 17 to September 6.

The Conference, first of its kind ever held on a world scale, has been called by the United Nations Economic and Social Council, and several hundred scientists are expected to participate. It will be held at the same time as a conference on the protection of nature, sponsored jointly by UNESCO and the International Union for the Protection of Nature.

Meetings in June

SOCIETY of Automotive Engineers. French Lick, Ind. June 5-10.

American Medical Association. Atlantic City, N. J. June 6-10.



HIGHEST ROCKET ASCENT was achieved on February 24 over White Sands Proving Ground, N. M., by a Wac Corporal rocket. Here the Wac Corporal is in the nose of a V-2, which carried it to a height of 20 miles. From there the Wac Corporal climbed to 250 miles, bearing a payload of telemetered instruments. It reached its maximum height in six and a half minutes, crashed five and a half minutes later. The hull has not been found.

ROCKETS

The historic method of propulsion is also the most modern. The central problem is fuel, the development of which may presently liberate man from the earth

by Willy Ley

ON February 24, 1949, man made his first really substantial step into outer space. On that day an ex-German V-2 rocket took off from the White Sands Proving Ground in New Mexico. In its nose it carried, instead of the customary one-ton "warhead," an American-made rocket of the type known as the Wac Corporal, filled with telemetered instruments. The V-2 rocket by itself would have reached an altitude of about 110 miles. The Wac Corporal, taking off from the ground without a booster, would have attained an altitude of about 40 miles. But taking off from the V-2 at an altitude of more than 20 miles, and starting at a velocity of a mile per second before it had even begun to burn its own fuel, the Wac Corporal attained a maximum velocity of 1.39 miles per second and then coasted upward to an altitude of 250 miles before earth's gravity won out over its kinetic energy and began to pull it back.

While definitions of the limit of the earth's atmosphere differ, it is generally agreed that the pressure at 250 miles above sea level is virtually zero, so it is fair to say that at the peak of its ascent the Wac Corporal was in interplanetary space. This historic event took place three years to the day after the first rocket of its type had taken off from the White Sands Proving Ground. If the recent rate of progress in rocket research is maintained, the day when man will realize his ambition to fire a missile to the moon or beyond is not too far off.

Rockets have come a long way since the first liquid-fuel rocket of the German Rocket Society lifted itself from the ground on May 10, 1931, and climbed to all of 60 feet; or since Robert H. Goddard's first liquid-fuel rocket rose near Auburn, Mass., on March 16, 1926, and crashed 184 feet from its takeoff point; or since that day in 1911 when the Frenchman F. Ferber de Rue, one of the early aviators, wrote in the last chapter of a small book on flying: "In order to go higher, and man will want to go higher, it will be necessary to adopt a different principle. The principle of the rocket, which will lead to a reaction motor, is indicated."

The rocket principle itself is many centuries old. From about 1805 to 1830 the rocket was a much-feared "secret weapon" of the British. They used it all over the world, including North America—which led to the lines in our national anthem on "the rocket's red glare, the bombs bursting in air," the bombs being the rockets' warheads. Still earlier, pirates had used rockets to set their enemies' tarred rigging afire. The earliest European reference to rockets that can be given a definite date was in the City Chronicle of Cologne for the year 1258. Learned Arabs of the same period also knew of rockets; they called them *alsichem alkhatai*, or "Chinese arrows." Most likely the rocket was actually invented in China. Chinese chronicles are neither complete nor reliable, but the French Sinologist Stanislas Julien succeeded in finding a description of something like a rocket in a work of the year 1232. No earlier references are known.

The Early Rockets

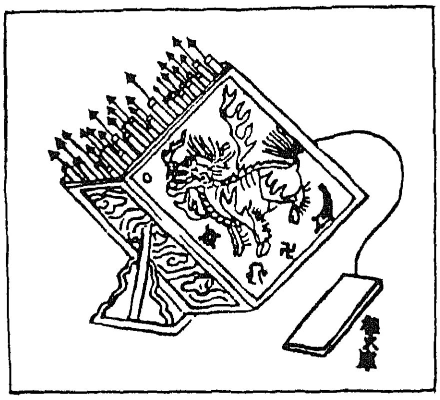
Aside from a few experimental curiosities of the 18th and 19th centuries that ran by the expulsion of steam, all rockets made before 1920 were fueled by black powder At first the powder used was the same as that in guns, but as gunpowder improved, it became too violent for the propulsion of such rockets as were made in those days. It had to be slowed down—pyrotechnicians spoke of "making it lazy"—by addition of extra charcoal. Good black powder for guns had a composition by weight of about 75 per cent saltpeter, 15 per cent charcoal and 10 per cent sulfur. The numerous rocket recipes recommended around 60 per cent saltpeter, 25 per cent charcoal and 15 per cent sulfur. In fireworks rockets, fine metal filings were often added to produce a shower of pretty sparks in the exhaust. The rockets were all straight tubes into which the powder mixture was laboriously hammered in small portions, usually around a central "thorn" that was pulled out when the powder had been packed in. This left a hole in the center which, for reasons then unknown, was necessary for the functioning of the rocket.

After their early trials in warfare, rockets were abandoned as a weapon for several centuries, not for moral reasons but because large rockets had the nasty habit of exploding during manufacture. By about 1450 they had largely ceased to be employed in warfare on land, though incendiary rockets lingered on at sea for another three centuries. War rockets persisted longest in industrially backward countries: to make rockets one needed only a workshop, whereas to cast cannon and shot required a foundry.

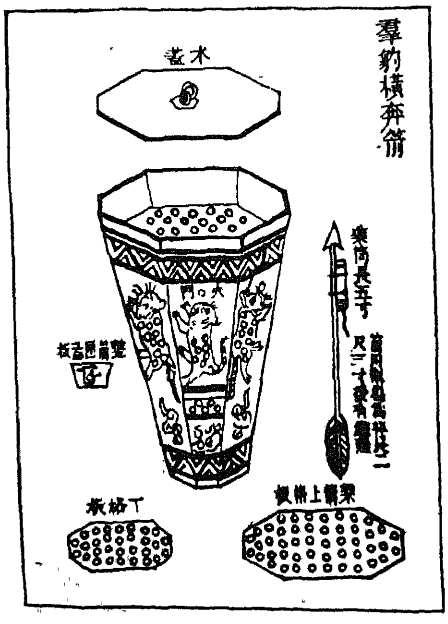
Near the end of the 18th century British troops fighting in India suffered some surprising defeats at the hands of Hindus armed with rockets. When the news of these defeats and the reason for them reached England, a major in the Royal Artillery named William Congreve decided to look into the matter. He bought some rockets at his own expense and began to experiment with them. His experiments were so successful that 10 years later he was General Sir William Congreve.

In about 1680 Sir Isaac Newton had published his Third Law of Motion—every action has an equal and opposite reaction—which governs the performance of rockets. Some 20 years before Congreve went to work, a French refugee physicist living in London, one Dr. Desaguliers, had even written a popular book in which he pointed out, among other things, that the recoil of a rocket should operate in empty space, or a vacuum, as well as it does in air. (Actually it works somewhat better in a vacuum.) So the theory and the necessary

CHINESE may have used rockets as early as 1232. Here incendiary rocket arrows are launched from baskets.



LAUNCHER built by the Chinese had a capacity of 100 rocket arrows. It could be tilted to alter its range.



PORTABLE launcher had a capacity of 40 rocket arrows. These rockets had a range of some 400 feet.

mathematical tools for a scientific investigation of rockets were already available. Congreve, however, did not make such an investigation, he simply improved the construction of the type of rocket that medieval artisans had developed by rule of thumb.

The artisans had known that a rocket will tumble end over end unless it is provided with a guiding stick. True, during the early 17th century an unknown inventor had devised guiding fins, but Congreve preferred the guiding stick, even though it was a dead weight amounting to almost 40 per cent of the rocket's total mass. Instead of attaching it to the side of the tube, however, as had been customary, he fastened a three-pronged fork to the lower end of the rocket tube so that the stick was held in line with the rocket's axis. Congreve also discovered a way to prevent the rocket from exploding while the powder was being hammered in. When a powder mixture is compressed by hammering, the air trapped between the fine powder grains also is compressed, and the heat thus generated may be great enough to ignite the powder. Congreve was probably not aware of this basic explanation, but he found by empirical tests that the powder could safely be hammered if it was moistened with alcohol, the result, we know now, is that much of the air is replaced by an incompressible liquid which also absorbs some of the heat. Congreve, in addition, substituted a drop hammer for the hand-wielded mallet. With all these improvements Congreve produced a practical incendiary weapon that had a range of 3,000 yards, putting it on a par with the biggest mobile guns of the time.

The British introduced this weapon to the world in two very effective rocket raids on Boulogne and Copenhagen in 1806 and 1807. Overnight, rockets excited intense interest among military men in all countries, just as they do today. Austria, France, Poland and Russia went in for experimentation to develop their own types, but most of the other nations were satisfied to buy their rockets from England

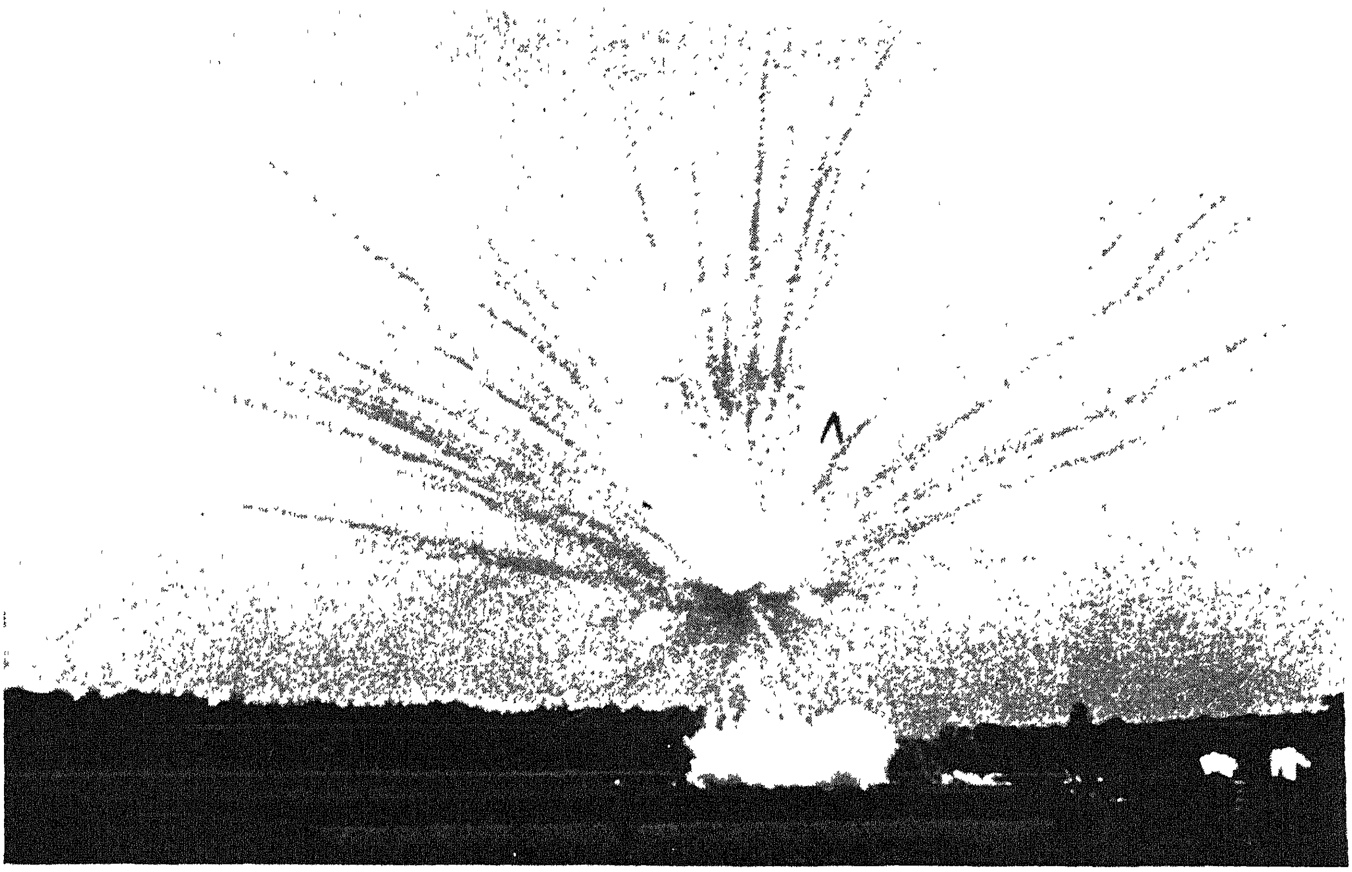
It was the British again who produced the next important improvement: a stickless rocket. Its inventor, William Hale, got rid of the stick by placing in the exhaust three metal vanes that made the missile rotate and thereby gave it stability in flight. Hale rockets were adopted by the U. S. Army. But by that time most of the hastily organized rocket corps in European armies had been disbanded. A new drawback had appeared: the black-powder rocket became unstable after a period of storage, for the compressed powder grew very brittle. Accidental dropping or even sudden changes of temperature produced cracks in the powder that caused explosions when it was ignited. In the First World War the only nation that used rockets to any appreciable extent was France. French biplanes carried large naval signal rockets, and used them to shoot down German captive balloons bearing artillery observers

Rocket Theory

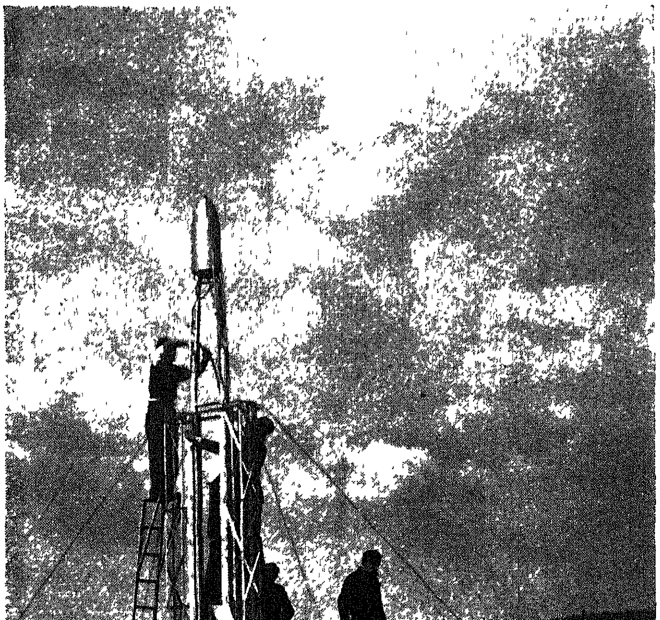
The scientific investigation of rockets did not begin in earnest until the 1920s. To be sure, the fundamental principle was already well known, it was expressed in a simple formula derived from Newton's Third Law of Motion: $MV=mc$. M and V were, respectively, the mass and the velocity of the rocket, and m and c signified the mass and velocity of the exhaust. Since air resistance did not enter into this formula at all, it meant that the motion of the rocket was independent of the surrounding air. The 18th-century Frenchman Desaguliers had explained this as follows: If you imagine a container filled with a compressed gas, the gas will exert equal pressure on all parts of the inside of the container's wall. But if the container suddenly acquires a hole where the gas can escape, there can be no pressure on the area of the hole. There must be surplus pressure on the wall opposite the hole. And if the pressure exerts enough force it will move the container in that direction, opposite the direction of the exhaust.

To calculate the thrust thus exerted, differential equations were needed. After many errors, the correct equation was found to be. $P=c \times dm/dt$. This means that the thrust, P, is determined by multiplying the exhaust velocity, c, by the mass of the exhaust during a given time interval, say the number of grams per second This equation at once made clear why the center hole in the solid fuel is needed. If the fuel filled the tube, the burning area would be only the cross section of the tube at the rear end of the rocket, and the mass of the expelled gas, or exhaust, would be at a minimum Under these conditions the factor dm/dt would not be large enough to make the thrust, P, greater than the weight of the rocket. The function of the center hole is to increase the burning area, which is now the entire inside surface of a cone or a cylinder, depending on the shape of the hole, instead of just the cross section. The hole in the tube shortens the duration of the thrust, both by increasing the fuel consumption per second and by reducing the amount of fuel carried by the rocket, but it makes possible the power necessary to lift it. The equation also showed that the chief purpose served by the hammering of the powder was to pack as much "gas" (in its state prior to combustion) into the tube as possible.

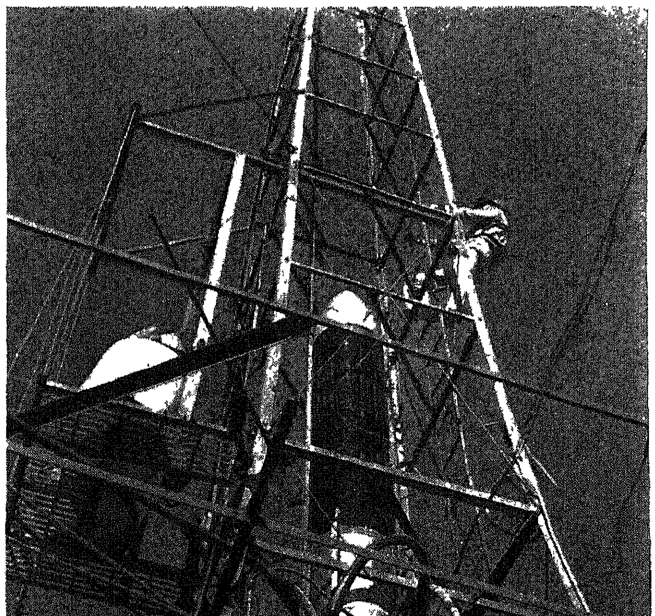
This theoretical knowledge became generally available a few years after the First World War, but for a while attention was focused mostly on the brittle-



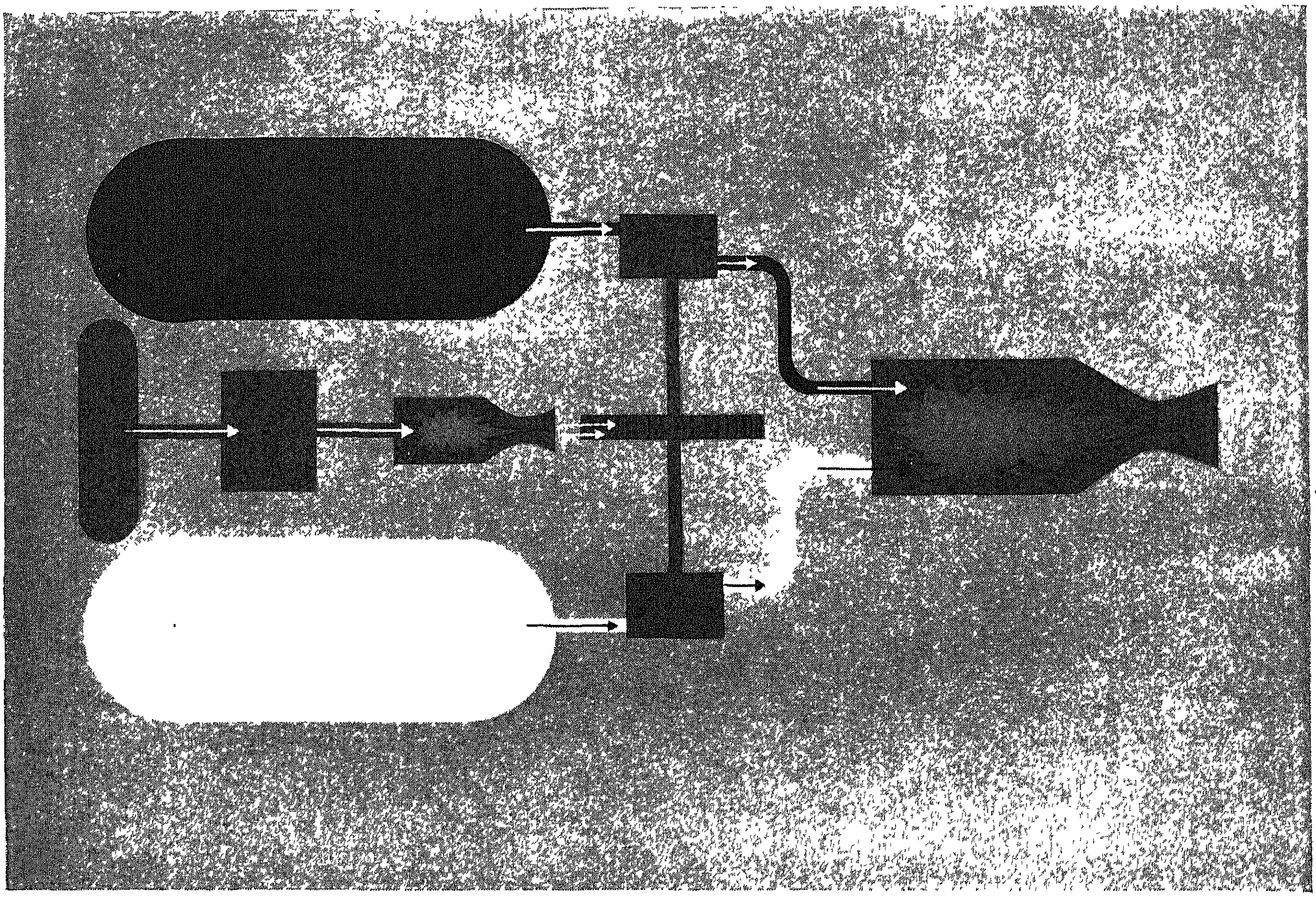
ROCKET EXPLODES during a German demonstration of the 1930s. This rocket had been made by Reinhold Tiling, one of the early German rocket workers. Tiling, however, was not in the advance guard of rocketry. His rockets burned solid fuels. They also were fitted with wings, a pair of which is above explosion.



LAST EXPERIMENT of German Rocket Society was conducted on a lake near Berlin in 1933. Society soon disbanded. German Government carried on later work.



EARLY U. S. ROCKET is prepared for launching in Robert H. Goddard's tower near Roswell, N. M. Rocket was launched in 1940. At the left are oxygen tanks.



BASIC CONSTITUENTS of a liquid-fuel rocket are outlined in this drawing. At upper left is oxidizer tank. At lower left is fuel tank. Oxidizer and fuel are fed into motor at right. Between tanks is an auxiliary motor which runs a turbine (*center*). This in turn runs oxidizer and fuel pumps (*above and below turbine rotor*).

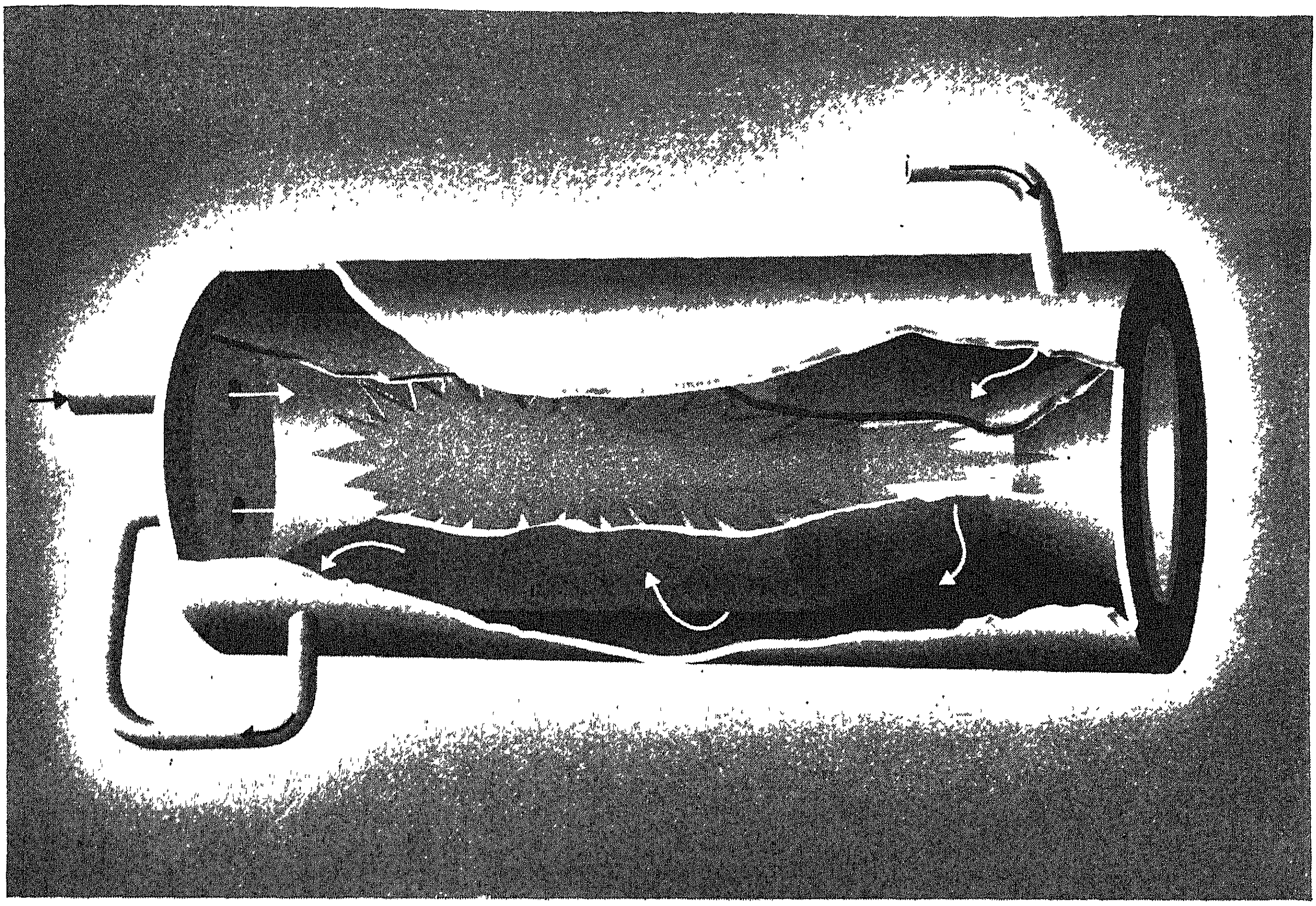
ness of black powder. Military men began to investigate smokeless powder for rocket propulsion. Smokeless powders, especially the so-called "double-base" powders first compounded by Alfred Nobel, were not brittle and were more impervious to temperature changes. They also had a higher energy content. The most carefully compressed black-powder mixtures produced an exhaust velocity of about 2,000 feet per second. With double-base powders one could hope for 4,000 to 5,000 feet per second.

The two bases used by Nobel were nitrocellulose and nitroglycerine. The manufacturing process amounted to making nitrocellulose gelatinous by means of a substance which was a high explosive itself. Nobel's materials, with the addition of stabilizers, became the basis of the modern solid-fuel rockets The British developed a rocket powder mixture composed of 50 per cent nitroglycerine, 41 per cent nitrocellulose and 9 per cent diethyl diphenyl urea. The U. S. powder had a similar composition: 60 per cent nitrocellulose, 40 per cent nitroglycerine and a small addition of diphenylamine. In all likelihood the Germans also began with one of Nobel's mixtures, but they looked around for a substitute for nitroglycerine, since glycerine is derived from fats which might be scarce in time of war. Somebody thought of using diethylene glycol dinitrate. The substitute proved to be better than the original; it was less sensitive and superior as a gelatinizer.

With the change in propellant went a thorough change of design. The old tightly fitting powder charge with a center hole, designated as a "restricted burning rocket," was replaced by an "unrestricted burning rocket," consisting of a warhead and a powder stick freely suspended in a steel tube. These parts can be mass-produced by virtually automatic machinery. The powder sticks are either thick-walled tubes, burning from the outside in and from the inside out, or thick-armed crosses Both shapes burn in such a manner that the factor dm/dt remains nearly constant. The factor is high, for the burning time of bombardment rockets is about three seconds.

Rocket engineers had no sooner created this powerful design than they found it necessary to change direction and reduce the factor dm/dt. The reason was that rockets were also needed as takeoff assistance for airplanes, and this required a burning time of at least 20 seconds. They therefore returned to the old restricted burning rocket, even to the type without the center hole. A new family of propellants had to be developed, and they received the name of "cast propellants." This name at once suggests TNT, which is poured into shells in a molten state. The Germans actually tried a fuel containing 50 per cent TNT.

In the U. S. the problem was solved by a method described in the so-called JPL (Jet Propulsion Laboratory) Report of the California Institute of Technology. The engineers in charge rejected a double-base powder because it appeared doubtful that an exhaust nozzle would be able to stand the heat of the exhaust for the duration required, from 20 to 40 seconds. The propellant they developed (it was later superseded by improved fuels) was called GALCIT 53, a name derived from the initials of the Guggenheim Aeronautical Laboratory, California Institute of Technology. It was a mixture of potassium perchlorate, as the oxygen carrier, and a special variety of asphalt, the fuel. It looked like black paving tar and had a similar consistency; it could be ignited with an ordinary flame, but not easily. Once ignited it burned well with an intense white flame, generating very large quantities of dense white smoke. "Burning in a combustion chamber under a pressure of 1,600 pounds per square inch," said the report, "the propellant gives an average exhaust velocity of 5,300 feet per



REGENERATIVE MOTOR is a fundamental concept of modern rocket technology. Reaction of oxidizer and fuel takes place in innermost chamber. Before entering the chamber fuel is circulated through a jacket around it. This cools the chamber and heats the incoming fuel. Oxidizer is fed directly into the chamber (*upper left*).

second at an average burning rate of 1.25 inches per second."

A New Principle

From the point of view of a chemical or military engineer all this constituted enormous progress, but in the eyes of a rocket theorist it merely solved Congreve's relatively minor problems. The more fundamental improvements that finally resulted in that first step into space on February 24, 1949, required a different approach. This approach consisted in developing a comprehensive theory first and worrying about the engineering aspects afterwards.

Chronologically the first to suggest the key to the new approach was a Russian schoolteacher named Konstantin Eduardovitch Ziolkovsky. In 1903 he proposed the revolutionary idea that rockets should be designed for *liquid* fuels. Although eminent scientists (among them Dmitri Mendeleyev, author of the periodic table of the elements) encouraged him, his work is only of historical interest. He failed to influence experimental researchers in Russia, and his name remained unknown elsewhere because nobody ever translated his writings.

The first modern publication on rocket theory was Robert H. Goddard's oft-mentioned Smithsonian Report of 1919, entitled *A Method of Reaching Extreme Altitudes*. Goddard briefly mentioned liquid fuels in this report, but failed to place emphasis on the importance of this concept. In 1923, however, a small and highly technical book that was to have great practical consequences appeared in Germany. It was written by a young professor of mathematics named Hermann Oberth, a native of Transylvania. An unapologetic discussion of the theoretical aspects of interplanetary travel, the little book considered rocket theory in all its applications, from a small instrument-carrying rocket to a manned space ship. Its distinguishing feature was Oberth's strong argument for liquid fuels. He suggested alcohol and liquefied hydrogen as likely fuels, with liquid oxygen as the oxidizer.

Practical engineers were amused at the notion of using substances like liquid hydrogen and liquid oxygen in tank-car lots. I remember listening to a speech by a man, considered an eminent authority on liquefied gases, who declared with great emphasis that any fuel in contact with liquid oxygen would not burn at all but would always explode. Oberth's idea was hotly discussed for years on false assumptions of this kind and on irrelevant issues, some of which were introduced by Oberth's own supporters. They laid great stress, for example, on the fact that liquid fuels were theoretically capable of producing a higher exhaust velocity than black powder. But the higher exhaust velocity was an incidental factor, for it eventually became possible to produce solid fuels with an exhaust velocity close to that of liquid fuels.

Oberth's suggestion had much more revolutionary implications. One affected the control of a rocket's flight. There was nothing anybody could do with a solid-fuel rocket after it had been ignited. It could not be slowed down nor turned off. In rockets using liquid fuels, on the other hand, the rate of burning could be adjusted by means of valves and injection nozzles; either by means of a radio signal or directly, in a manned rocket, the rocket motor could be throttled or shut off completely.

But by far the most important gain was a radical change in the rocket's "mass ratio," meaning the ratio between the takeoff weight and the weight after all the fuel has been burned. The takeoff weight is made up of the payload, the rocket structure and the fuel load. Obviously the greater the fuel load carried by a rocket of a given size, that is, the higher its mass ratio, the greater is its potential speed. Mathe-

matical investigation showed that the performance of a rocket could be determined by the following formula: $M_0/M_1 = e^{v/c}$. Here M_0 is the takeoff weight, M_1 the remaining weight, v the maximum velocity, c the exhaust velocity and e the base of the so-called natural logarithms, 2.7182818. To calculate the required mass ratio for a desired performance it is only necessary to find the maximum velocity needed for that performance, divide this velocity by the exhaust velocity available and use the result as the exponential factor on e. This formula is valid only in a space without any resisting medium and without gravitational fields to be overcome; it does not work for small fireworks rockets under actual conditions. But the larger the rocket the closer the agreement between formula and reality. In the case of a V-2, less than 30 per cent has to be added to the calculated value, and in the case of a rocket that could reach the moon only about 5 per cent needs to be added.

Now it is at once apparent that when it comes to mass ratio the solid-fuel rocket is at a decided disadvantage. The whole rocket structure must be strong and heavy to withstand the great internal pressure of combustion plus the heat generated by the combustion. The "fuel tank" and "combustion chamber" are one and the same. When liquid fuels are used, however, the tanks and the rocket motor are separate units, hence in a large rocket the tanks can be thin-shelled. In a relatively small rocket such as the Wac Corporal, the tanks must stand the same pressure as the motor, since the liquids are fed into the motor by gas pressure, but even so there is less pressure to withstand. The combustion pressure in a liquid-fuel motor is of the order of 300 pounds per square inch, while in rockets using powder explosives the combustion pressure may be several thousand pounds per square inch. This can be illustrated in practical terms by comparing actual rockets of the two types. The solid-fuel rocket known as Tiny Tim weighs 1,284 pounds, of which 590 pounds is warhead and 146 pounds is propelling charge. The mass ratio is 1.13 to 1. The liquid-fuel Wac Corporal has a takeoff weight of 665 pounds and a fuel load of 385 pounds. Its mass ratio is 1.73 to 1. In a large liquid-fuel rocket the mass ratio can be further increased by force-feeding the motor by means of centrifugal pumps instead of gas pressure, which makes it possible to reduce the weight of the tanks. Thus the V-2, with a takeoff weight of about 12 tons and a weight with warhead of four tons, has a mass ratio better than 3 to 1.

Practical Problems

Before anybody could build a rocket with a high mass ratio, a large number of engineering problems had to be investigated and solved. Building materials was one. The first motors were made of steel. It was supposed that steel, because of its mass, would absorb the heat of combustion with safety, as it does in a gun barrel. The idea did not work; the motors disintegrated. Then somebody had the idea of doing the opposite: of making the motor with very thin walls of a metal of high heat conductivity—pure aluminum—and cooling it from the outside by means of running water. That worked fine on the test stand, where unlimited quantities of cold water could be run through the cooling jacket, but in rising rockets cooling became a problem of a much higher order of difficulty. One method that was attempted was putting the motor inside the liquid oxygen tank, in the hope that the liquid oxygen would help in cooling without increasing the weight. The tank exploded. It had been forgotten that a liquid gas, while extremely cold, is a poor cooling medium because, being near its boiling point, it cannot absorb any quantity of heat worth mentioning.

The cooling problem was solved, oddly enough, not by direct attack but as a by-product of studies of the fuel problem. Many fuels had been tried: gasoline, methane, benzene, even gaseous hydrogen. In the end the most efficient fuel was found to be Oberth's first suggestion—alcohol. An Austrian physicist, Eugen Sanger, published a timely book that presented tables relating to the theoretical performance of fuel-and-oxygen combinations. The most striking finding was that alcohol required the smallest amount of oxygen for combustion; it needed only 2.1 times its weight of oxygen, while gasoline, for example, needed 3.5 times its weight. And here emerged an answer to the cooling conundrum, for alcohol is a good absorber of heat, especially when it is mixed with water. Furthermore alcohol-water mixtures stay mixed in a tank while gasoline-water mixtures do not. How much water could the alcohol hold and still burn? My father, a wine merchant and liquor manufacturer, helped supply the answer. a mixture that contains more than 40 per cent of alcohol (over 80 proof) can be ignited in air.

Klaus Riedel of the German Rocket Society then ran a few tests, beginning with 60 per cent alcohol and working down to 35 per cent; in pure oxygen instead of air even this watery mixture would burn. In 1931 the first rocket motor using watered alcohol as fuel was built. The fuel was run through the cooling jacket before it was injected into the motor. It did double duty, serving as a coolant first.

Much later, after the German Rocket Society had been dissolved and the German Army had taken over rocket experimentation on Peenemünde in the Baltic, Oberth discovered another interesting fact about alcohol-water mixtures. Naturally the exhaust velocity depends on the average molecular weight of the exhaust. The exhaust is a mixture of carbon dioxide and water molecules. The latter are far lighter. By adding water to the fuel the relative number of water molecules is increased, the average molecular weight of the exhaust drops, and the exhaust velocity goes up. Of course there is a limit to this, else water would be the superior fuel. Oberth found that the optimum result was obtained when the admixture of water to alcohol was slightly above 25 per cent. And that mixture of 75 per cent ethyl alcohol and 25 per cent water became the fuel of V-2 and later of the U. S. rocket airplane designated XS-1.

But even with as good a coolant as watered alcohol the big motor of V-2, made of formed sheet steel sections which were then welded together, did not stand up well enough. It burned through in the place where rocket motors are in the habit of burning through, near the so-called "throat," the narrowest section of the exhaust nozzle. Yet the answer, when it was finally found, was simplicity itself. All that was needed was to drill a number of fine holes through the wall of the exhaust nozzle so that fine sprays of watered alcohol could enter this part of the motor directly from the cooling jacket. The alcohol was carried along by the exhaust blast to form an insulating layer between exhaust and nozzle wall. Lacking a supply of oxygen, it did not burn and was a waste of fuel, if you like, but it made the motor stay in one piece for 70 seconds.

The Modern Versions

The V-2 has had a number of successors in the U. S., all different in size, design and purpose. The Wac Corporal came first, then the Aerobee, the Convair 774 and the North American Aircraft Nativ. Even while V-2 was under development there were a number of other types in Germany: the Peenemünde rocket A-5, the anti-aircraft missile *Wasserfall* and the small anti-aircraft rocket *Taifun* (typhoon).

These rockets used various fuels. While the watered alcohol and liquid oxygen combination is almost ideal, it does have a major drawback. The boiling point of liquid oxygen is almost 200 degrees Centigrade below the freezing point of water. Hence a rocket using it cannot lie around waiting. It is a case of "fuel and fire." But the Germans wanted a rocket that could be used as an anti-aircraft weapon, which meant, of course, that fully charged rockets had to be held in readiness, waiting. And this meant doing without liquid oxygen.

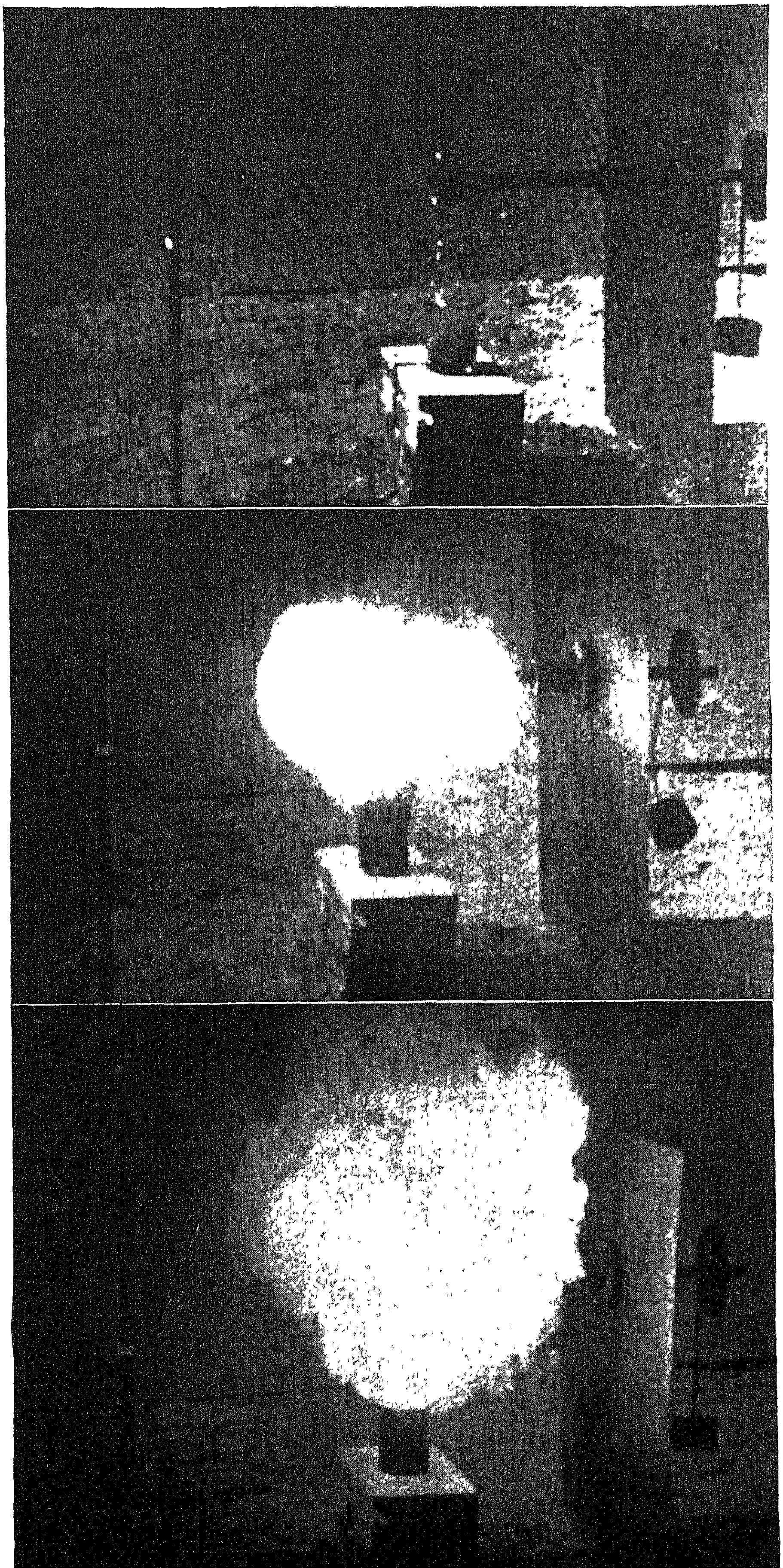
Wasserfall and *Taifun* were developed as anti-aircraft rockets. They were actually built and tested but did not reach

the stage of readiness for production and military use before the end of the war. *Wasserfall*, a guided missile, looked like a small V-2, except for a set of stubby mid-body wings. It stood some 24 feet tall and had a takeoff weight of slightly over 7,600 pounds, of which 4,100 pounds was propellants. Since the motor thrust at takeoff was 17,600 pounds, its effective takeoff acceleration was about 1.3 g, or 1.3 times the acceleration of a body falling under the influence of the earth's gravity. This was slightly higher than the takeoff acceleration of V-2. *Wasserfall* operated without pumps, fuel feed being accomplished by air pressure. The oxygen carrier for this missile was nitric acid, to which 10 per cent of sulfuric acid was added. The fuel was vinyl isobutyl ether, code-named *Visol*. Originally the design had called for light metal alloys for almost everything except the motor and the acid tank; actually it was built of steel, just like V-2.

If *Wasserfall* was quite conventional in design, the unguided rocket *Taifun*, a small, high-velocity missile that was to be fired in swarms, was quite radical. The rocket, cylindrical in shape except for the pointed warhead, was four inches in diameter and 75.6 inches tall. The cylindrical body served as tank for the *Visol*. Inside was a second, concentric cylinder that served as the tank for the acid. The two liquids were forced into the motor by gas pressure. It was not compressed gas, however, but the gas developed by a burning disk of cordite. The rocket on takeoff weighed not quite 43 pounds, of which 21.6 pounds was propellants. And it took off with an acceleration of 31 *g*. Three seconds later the acceleration had risen to 45 *g*.

The Peenemunde rocket A-5, designed for research tests of instruments and mechanisms to be used in other rockets, was 16.5 feet tall, with a maximum diameter of two feet. It reached an altitude of 40,000 feet when fired vertically. It came down by parachute—the only reasonably large rocket so far that has been retrieved without destruction. (In the larger rockets valuable individual instruments are recovered by means of small parachutes.) It was also the only rocket for liquid fuels that used a so-called mono-fuel: highly concentrated hydrogen peroxide.

Hydrogen peroxide (H_2O_2) had previously been known mainly in weak solutions; the household variety has a strength of four per cent. Higher concentrations were known to decompose according to the formula: $2H_2O_2 \longrightarrow 2H_2O + O_2$. This reaction releases enough heat to raise the temperature of the decomposition products to about 950 degrees C. It had always been thought that hydrogen peroxide could not be manufactured and stored in high-strength solutions in large quantities. After much research, the Germans suc-



SPONTANEOUS IGNITION of aniline and red fuming nitric acid is photographed at 64 frames per second in the Jet Propulsion Laboratory of the California Institute of Technology. This combination propels Wac Corporal.

ceeded in making it comparatively safe, provided that two conditions were fulfilled. One was to keep impurities (not counting the water, of course) down to a few parts in a million. The other was to keep any trace of copper out of the metal parts that might touch the peroxide. Copper-free nickel alloys or absolutely pure aluminum were used as construction materials for these parts. The reaction was started catalytically, by the addition of sodium or potassium permanganate. The reaction that propelled the A-5 was also used in the V-2, for the purpose of generating steam for the turbine that was to drive the fuel pump.

Refinements

Meanwhile the engineers at Caltech's Jet Propulsion Laboratory were busy developing not only improved solid fuels but a liquid-fuel booster unit for airplanes to assist in takeoff. They knew what they wanted to use for an oxidizer: nitric acid. At first they used what is known as "white acid"—relatively pure HNO_3. The results were not good. They switched to $HNO_3 + NO_2$, the red fuming nitric acid of commerce. It did better, but still not as expected. Then one of Caltech's researchers, Dr. Frank J. Malina, learned that another group of researchers at Annapolis was having the same trouble. Visiting them, he learned that they had considered adding something to their gasoline for better performance, possibly aniline. Why not use pure aniline? Dr. Malina wired the suggestion to his men in Pasadena. The result was an excellent motor, cooled by its own fuel and needing no ignition, since aniline and nitric acid burst into flame spontaneously upon meeting.

This became the motor of the Wac Corporal. A cylindrical rocket with a long conical nose, the Wac Corporal is 16 feet tall and one foot in diameter. Its burning period is 38 seconds. In its first ascent on February 24, 1946, assisted by a solid-fuel takeoff booster, it reached a height of 230,000 feet.

In spite of its military designation, the Wac Corporal is a peaceful rocket. It was designed as a carrier for instruments to high altitudes. But it fell short of the scientists' aims as an instrument carrier. Before the Wac Corporal, experimenters would have been enormously happy with any method of getting even a single instrument to altitudes above 200,000 feet, but they soon began to complain that the payload was not large enough. The result of these complaints was the Aerobee rocket.

As in the case of the Wac Corporal, the Aerobee's motor was developed and built by the Aerojet Engineering Corporation, and the rocket proper by the Douglas Aircraft Company. The technical direction was in the hands of the Applied Physics Laboratory of Johns Hopkins University. The Aerobee, 15 inches in diameter, stands 226 inches high, 88 inches of which is a long pointed nose housing the instruments to be borne aloft. Like the Wac Corporal, it takes off with the aid of a solid-fuel booster that raises its velocity to about 1,000 feet per second, whereupon the motor takes over. This motor, in 45 seconds of burning, adds another 3,100 feet per second to the speed and raises the rocket to a total altitude of 70 miles with a 150-pound payload of instruments. Larger payloads can be carried, but that, of course, reduces the peak altitude.

As far as published information goes, no parachute recovery of this rocket has ever been attempted, but the designers have thought of an interesting substitute. When the rocket descends, a small controlled explosion knocks off its tail fins. The rocket is then completely unstable, aerodynamically speaking, and it tumbles to the ground, thereby taking maximum advantage of the air resistance. Falling to earth at a speed of about 150 feet per second, it lands with an impact that is not great enough to destroy the instruments, especially on desert sand or soft soil. The first full-dress firing of an Aerobee took place on November 24, 1947.

The two newer rockets—774 (built by Consolidated-Vultee) and Nativ (built by North American Aviation)—are still largely secret. Both are liquid-fuel rockets. The rather large 774 has a potential altitude of 100 miles. The small Nativ rises only a few miles. Both are meant as practice missiles for the training of missile crews.

What Next?

As everyone knows, rockets are now being used for exploratory research. High-altitude shots with ex-German V-2s, Wac Corporals and Aerobees have provided a great deal of very interesting information about the density and temperature of our atmosphere at altitudes that were inaccessible only a decade ago. The solar spectrum has been considerably extended. The intensity and distribution of cosmic radiation has been measured. The intensity of the earth's magnetic field at high altitudes has been ascertained. The Aerobee has proved, among other things, that high-altitude rockets are extremely useful in taking photographs of inaccessible territory.

So far, however, the number of such shots has been small. It is still a kind of probing, reaching at intervals into the ionosphere with questing instruments. The thing still to be done is to repeat these probes often enough so that a statistical distribution of high-altitude conditions and phenomena can be established, around the clock and around the seasons. The findings will not all be meteorological. Aircraft designers will get whole sets of completely new data. Long-range, high-velocity transportation is likely to be the result. Very long-range weapons too.

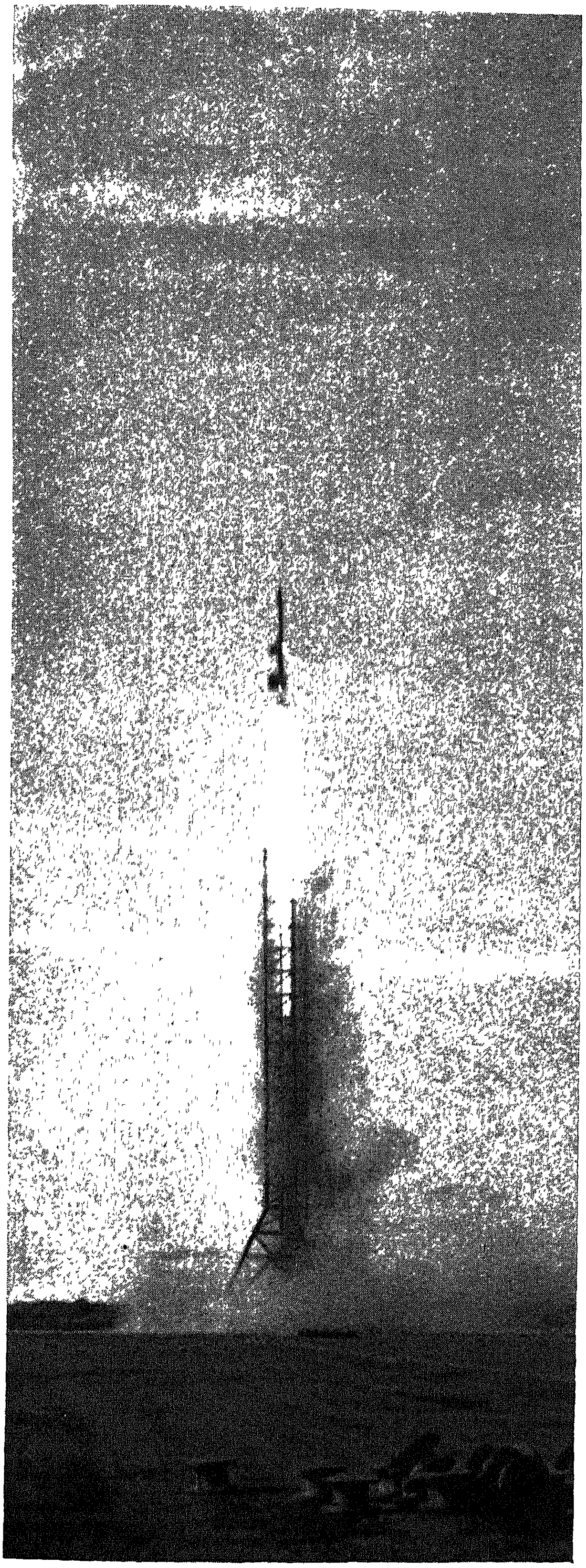
But the largest promise is contained in that shot of February 24, 1949. The promise is in the use of the step principle. Even with the utmost refinement of design, even with very light and wonderful pumps, there is a limit to the mass ratio a single rocket can achieve. If we say, pessimistically, that that limit is a mass ratio of 5 to 1, it means that the ratio between rocket velocity and exhaust velocity will be about 8 to 5, say 8,000 feet per second rocket velocity if the exhaust velocity is 5,000 feet per second. But if one large rocket of a mass ratio 5 to 1 carries a small rocket of the mass ratio 5 to 1, the ratio of rocket velocity in the upper step to exhaust velocity will be doubled, *i.e.*, it will be 16 to 5, and that corresponds to a mass ratio of 25 to 1.

If the principle can be extended to three steps, we may very well get a "satellite rocket" that will circle the earth indefinitely. If we extend it to four steps, the fourth step should pass across that line where the pull of the moon is greater than that of the earth. That fourth step will crash on the moon.

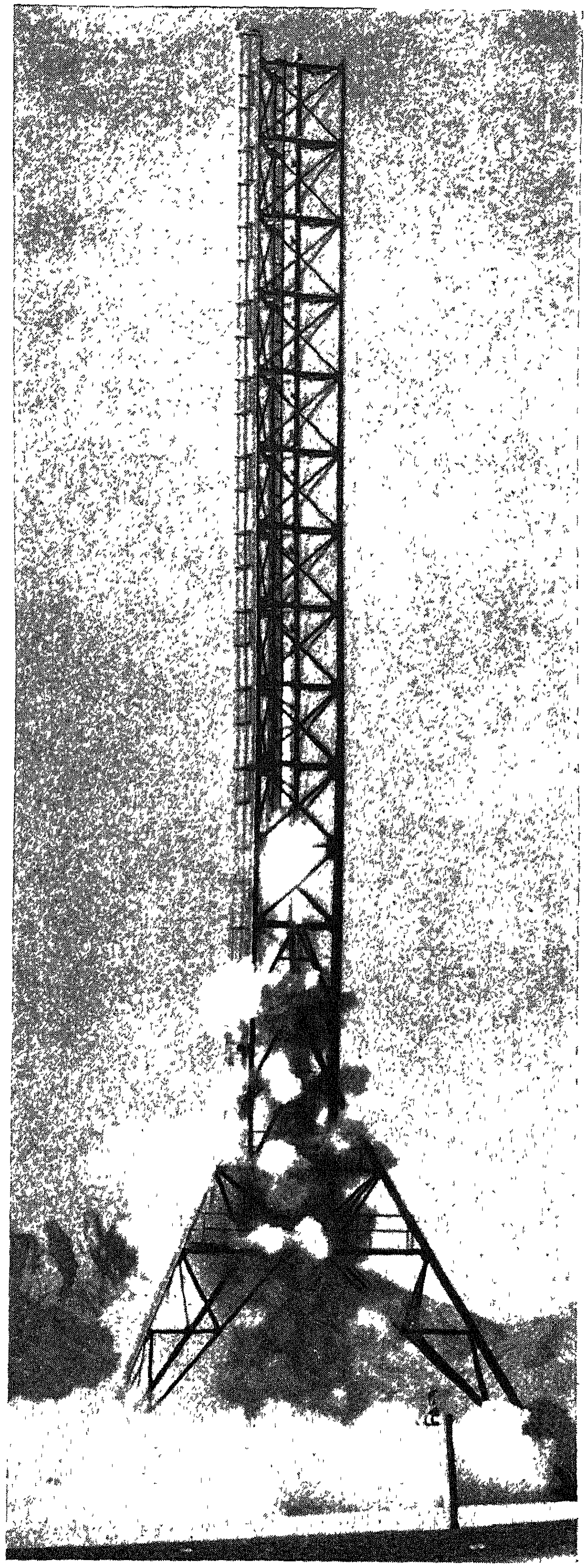
To crash a rocket on the moon may not have any practical value, but it would be a highly symbolic act. Once that has been done the step principle may be extended much farther. A rocket that moved around the earth as a small artificial satellite, if it was enlarged and manned, would be the most useful investment in the history of mankind. It would be a super-laboratory where any temperature might be created, where experiments could be carried out under apparently complete freedom from the effects of gravity. It would be a laboratory with a limitless vacuum at the disposal of the researchers. It would be a highly superior astronomical observatory; any existing telescope, raised there and freed from the interfering atmosphere, would be improved in seeing by some 300 per cent.

And finally, if fuels were accumulated on that station, so that a manned rocket could refuel, the satellite station would be the most effective "lower step" of all. It would be the solution of the problem of space travel—the ultimate goal of all rocket research. A ship capable of taking off from the ground and reaching such a station would also be fully capable, after refueling, of reaching the neighboring planets. Thus the shot of February 24th has opened a window with a view of the nearer areas of our solar system.

Willy Ley is a former member of the German Rocket Society and author of the book Rockets and Space Travel.



THE WAC CORPORAL is launched at White Sands Proving Ground. Flaming jet is from booster charge that pushes rocket during early part of its flight. This later falls away and motor of rocket proper begins firing.



THE AEROBEE, engineered by the Applied Physics Laboratory of Johns Hopkins University, is also lifted by a booster. Flame inside tower, however, is from the motor of the rocket itself, which has begun to fire.

PLANT HORMONES

Like animal hormones, they achieve powerful effects at a distance from their point of origin. Presenting a review of how they have been studied and applied

by Victor Schocken

MOST people are aware of the far-reaching effects of hormones upon their bodily functions and even their personalities. It is less widely recognized that in plants as well as animals hormones regulate the chemical reactions that comprise the life processes of the organism. The hormones of plants, like those of animals, are chemical substances that are produced in one part of the organism and affect a physiological process in another part. In plants the hormones originate not in special glands but in buds or certain other growing points. Some of them have been isolated in pure form. Moreover, just as drugs have been synthesized to simulate activities characteristic of hormones of the human body, so too synthetic compounds similar to the plant hormones have recently been developed. In other words, the plants have not only their adrenalin but their Benzedrine as well.

Obviously this means that man now has a practical means for the practice of therapy and control of the plant kingdom on a large scale. These natural and synthetic chemicals, which have been given the general name "auxins," have a powerful effect on the growth and health of plants even when used in very tiny amounts. Some of them are already in wide use by farmers and gardeners as weed killers and in other, more subtle, capacities, but the full exploration of their possibilities has barely begun.

The first observations that clearly suggested the presence of a hormone in plants were made by Charles Darwin during his study of phototropism, or the tendency of plants to incline toward a light source. This phenomenon had been observed long before Darwin, but he was the first to show that different parts of the plant were involved in receiving the stimulus and in responding to it. Working with the seedlings of canarygrass, oats, beans, and other grasslike plants, Darwin found that if the tip of the seedling was covered with a cap of tin foil or blackened glass, the plant failed to bend toward a light directed at it from one side. If, on the other hand, the seedling was buried in fine black sand and only the tip was exposed, the phototropic curvature did take place; in fact the whole plant bent through the sand toward the light when it was illuminated from only one side. Darwin also observed that if part of the tip was cut off, even as little as a tenth of an inch, the seedling no longer exhibited phototropism.

From these and many other experiments he concluded, as he reported in 1881 in *The Power of Movement in Plants,* that "when seedlings are freely exposed to a lateral light some influence is transmitted from the upper to the lower part, causing the latter to bend."

But how was the influence transmitted? The Danish botanist P. Boysen Jensen found that if an incision was made in the dark side of a unilaterally illuminated seedling, and a piece of mica was inserted in the slit, the stimulus was blocked and the seedling did not bend. The same operation on the illuminated side, however, did not interfere with the normal bending of the plant toward the light. Boysen Jensen concluded that the stimulus from the light passes down the dark side of the seedling.

He then cut off the upper part of a seedling, placed a drop of gelatin solution on the cut surface of the stump, and replaced the upper part, holding it in position by means of a ring of cocoa butter. When the replaced tip was then unilaterally illuminated, a decided curvature appeared in the part below the cut, which had been kept in the dark and was connected with the illuminated tip only through the gelatin. The stimulus had passed through the gelatin, a layer of nonliving matter. Clearly the transmission of the stimulus from the tip to the region of response did not depend on the vital process of the seedling.

IT was A. Paál, working at the University of Utrecht in Holland, who finally showed that the phototropic response is due entirely to a growth substance which is asymmetrically distributed in the plant. He demonstrated that if the tip of a seedling was cut off and replaced so that it covered only one side of the stump, greater growth occurred on that side and marked curvature of the plant resulted. This experiment conclusively proved the movement of a growth-regulating substance from the tip of the seedling to the lower parts, and it showed in addition that if one side of the seedling receives a higher concentration of this substance, then that side grows more rapidly and the seedling bends in the opposite direction.

The problem now was to extract the unknown substance. Continuing the work at Utrecht, F. W. Went (now at the California Institute of Technology) cut off the tips of several oat seedlings, placed them on a block of agar, and then placed the agar atop one side of a decapitated oat seedling. As in Paál's experiment, the seedling curved away from the block, showing that growth hormone from the tips had diffused through the agar into the plant. Went found that the amount of curvature was proportional to the number of tips used, which served as a rough measure of the concentration of growth hormone in a block. This observation gave rise to the *Avena* test (named for the genus of plants that embraces oats), which is still a standard method of quantitatively assaying for growth substances. The present *Avena* test uses agar blocks, but a more precise standard of measurement than plant tips.

With a method of assay for growth-hormone activity at hand, biochemists became interested in this field of research. They could now determine the relative abundance of the hormone in various materials, and could follow the activity of the hormone through extractions, concentrations or other chemical treatment. If by means of the *Avena* test they could find some abundant, auxin-rich material, then a chemical isolation of the hormone would be possible. Fritz Kögl and his group at the University of Utrecht undertook that search. In the course of testing a great variety of substances, they found that human urine is rich in growth substance. They therefore obtained about 40 gallons of urine from a hospital and proceeded to concentrate the hormone activity by chemical treatments. They eventually obtained 40 milligrams of crystals that had an activity 50,000 times as great as that of the original urine. This tiny pile of material, no larger in aggregate bulk

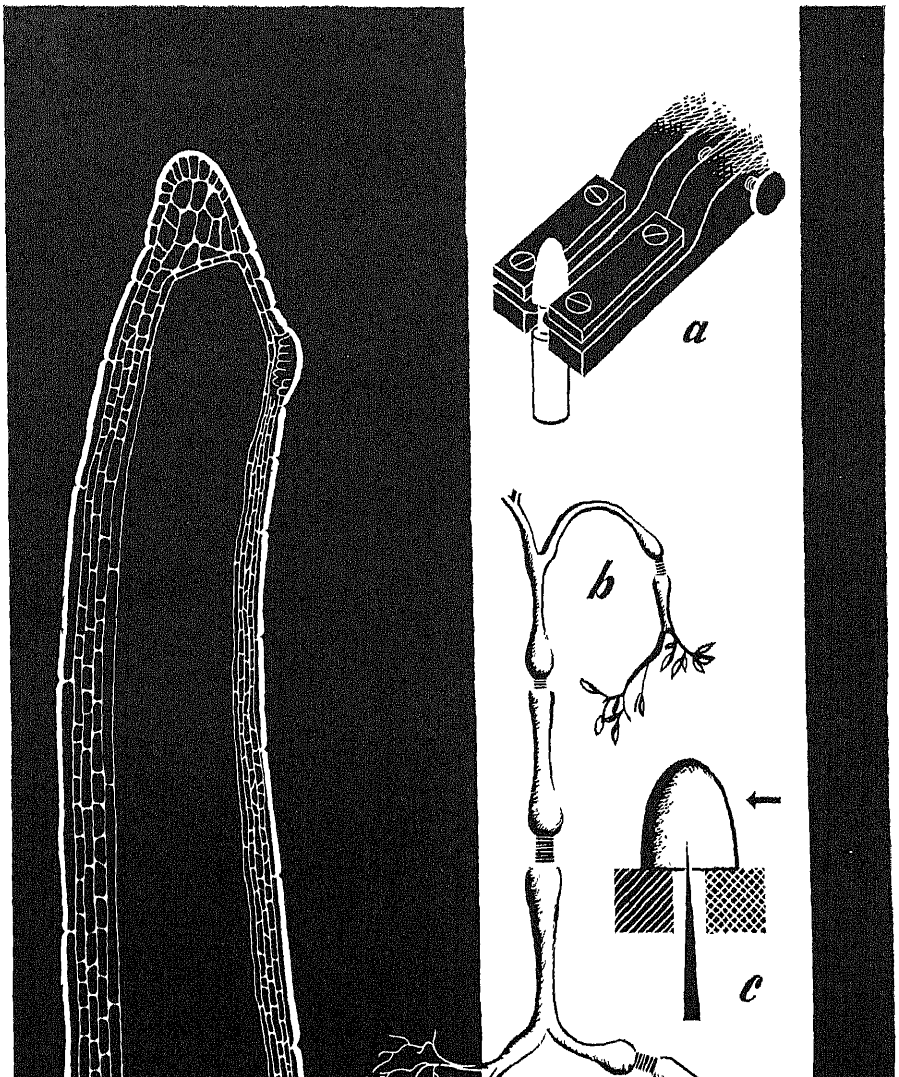
than a half-carat diamond, was so concentrated that, dissolved and diluted, it would have been sufficient to induce 10 degrees of curvature in each of two billion oat seedlings. Upon chemical analysis the active substance was found to be a new compound, $C_{18}H_{32}O_5$. It was named auxentriolic acid or auxin a.

In the same year, 1934, a second active substance was isolated from corn-germ oil by a similar procedure of extraction and concentration. This substance, which is quite similar to auxin a, has the formula $C_{18}H_{30}O_{10}$. It was called auxenolonic acid or auxin b. And finally, in the course of repeating the isolation from urine on a larger scale, the Kogl group isolated a third growth substance, indole-acetic acid, a compound which had been familiar to chemists for 50 years, though not until then recognized as a growth substance.

THE problem remained to determine which of the three was the natural growth hormone in plants. By a process of elimination depending on the molecular weight and chemistry of the active material, it was determined to be auxin a, but more recently indole-acetic acid has also been isolated from plants. In any case, it was the discovery of the growth-promoting activity of the common chemical indole-acetic acid that made possible the vast research program that followed. Not only indole-acetic acid itself but many of its close chemical relatives, such as indole-propionic acid and naphthalene-acetic acid, were found to possess growth-promoting activity. Plant scientists were thus provided with an array of relatively simple and easily available organic compounds to use in further experimentation.

Indole-acetic acid has become the standard by which the growth-promoting activity of a substance is measured in the *Avena* test. The test is carried out in the following way: Seeds of a genetically pure strain of oats are stripped of their husks, are germinated on filter paper moistened with distilled water, and then are grown in glass holders. When the seedlings are about an inch high, the tips are removed, and the decapitated plants are divided into two groups. On one side of the stumps of one group are placed agar blocks containing known amounts of indole-acetic acid. On the other group are placed agar blocks of the same size and composition but containing the substance to be tested instead of indole-acetic acid. After 90 minutes of growth, all the seedlings are photographed and their curvatures are measured. By comparing the curvature produced by the unknown substance with that produced by indole-acetic acid, a quantitative estimate of the auxin activity of the unknown is obtained.

After their identification, the next important discovery about the auxins



EXPERIMENTAL ORGANISM used in many plant-hormone studies is the oat seedling, a vertical cross section of which is at left. The horizontal cross section is at lower right. At upper right (a) is the head of a pair of scissors used to decapitate the seedling. Below it (b) is a plant wounded in an early observation of hormone effects. In middle (c) is oat tip mounted on a razor blade for the phototropism experiment described in text of this article.

was that besides promoting the growth of seedlings they also influence the development of plant form and structure. It had long been known that while the main shoot of a plant is growing, its lateral buds are inhibited. If, however, the bud at the apex is cut off, the lateral buds begin to develop. It had been postulated that an inhibiting substance diffuses from the growing bud to the tissue below it. With the advent of synthetic growth substances this theory was corroborated. When the apical bud was removed from a shoot and a small quantity of indole-acetic acid was applied to the stump, the lateral buds did not develop. Thus indole-acetic acid, which in other experiments had been observed to promote growth, was found to possess the power to inhibit as well.

AT about the same time it was demonstrated that the auxins have root-forming activity. This was another illustration of the versatile way in which auxins affect growing plants. But it also had an immediate practical importance, for experiments performed on a great variety of plants showed that auxin applications are generally beneficial in bringing about the rooting of cuttings. This process, known as vegetative propagation, is extremely useful to the horticulturist, for by means of it a great many genetically identical plants may be made from a single individual, and a desired genetic pattern, as in a variety of apple, a seedless orange, or a rose of a new color, may be preserved from generation to generation. In practice the cutting is usually a twig with a few leaves on it, but sometimes leaves, pieces of stem or root, or even bulb scales may be used to start a new plant. Auxin-treated cuttings generally root more rapidly than untreated ones, and the roots are more abundant and stronger. Dipping cuttings into auxin solutions or powders has become standard horticultural practice, and there are on the market today dozens of preparations designed for the nurseryman or home gardener. Incidentally, it has been discovered that this same ability to promote root growth is possessed by the petroleum product ethylene, which also has the property of accelerating the ripening of fruit. Ethylene is given off by certain varieties of quick-ripening apples, and if such apples are put in an airtight container with green tomatoes the tomatoes have been observed to ripen faster.

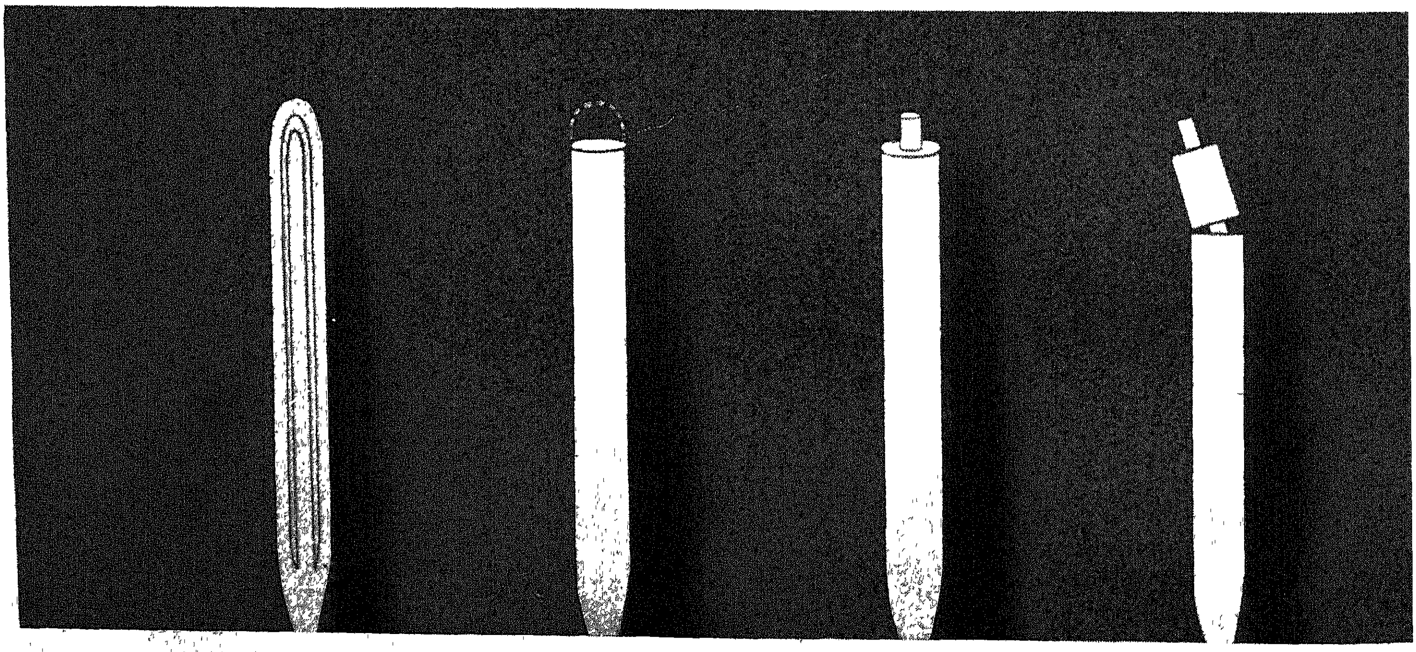
Another property of auxins that has grown to economic importance is their ability, when applied to the flowers of certain species, particularly the tomato, to initiate the development of fruit without pollination. Because of the difficulty of obtaining satisfactory pollination in a greenhouse where there are few insects and little wind, greenhouse growers of tomatoes are increasingly resorting to auxin treatments in the form of sprays or aerosol mists to improve fruit set. Fruits so induced are usually seedless; so besides increasing yields, auxin treatments may make possible the development of new seedless varieties.

In the raising of pineapples there is also some difficulty in obtaining satisfactory fertilization and development of the fruit. But here the problem is to obtain flowering of the plant at the proper time. The size to which the fruit develops is directly dependent on the number of leaves on the plant at the time of flowering. J. van Overbeek, working in Puerto Rico, found that the Cabezona variety of pineapple, which flowers poorly when left to itself, can be made to flower at any time of the year by a single application of an auxin (naphthalene-acetic acid or 2,4-dichlorophenoxyacetic acid). We therefore have the interesting possibility of producing uniform fruits of a selected size by applying the auxin to each plant when it has the appropriate number of leaves.

Although apples and pears need no such stimulation to flower and fruit abundantly, growers of these fruits use large amounts of auxins for still another purpose. One of the main sources of loss to apple and pear crops has been premature drop. From a fourth to half of the entire crop may be lost because the fruit falls before it has matured or developed good color. Thus the grower must either harvest before the best quality is attained or else risk a heavy fall. It had been observed that auxin applications delayed the fall of the leaves in *Coleus* plants, a genus of mint. Auxin sprays were therefore tried on apple trees to delay the fall of the fruit. This treatment proved highly successful, and now orchardists can obtain reasonable assurance against loss to their apple and pear crops by using any one of several specially prepared commercial auxin sprays.

Still another commercial application of auxins takes advantage of their growth-inhibiting ability. The methyl ester of naphthalene-acetic acid prevents the sprouting of potatoes in storage; thus the tubers will keep longer, even at warm temperatures. Nurserymen have found the same compound useful in storing quick-sprouting plants such as rosebushes.

One of the more recent additions to the auxin family is 2,4-D (2,4-dichloro-



AVENA TEST employs oat seedling to measure hormone present in a block of agar. At left is a complete seedling, a layer of cells surrounding a primary leaf. In second drawing the seedling is decapitated. In third the

phenoxyacetic acid). This compound has received wide acclaim as a weed-killer, for when sprayed on plants it kills the broad-leaved dicotyledons (the great subclass of seed plants that includes most herbs and shrubs), while sparing the grasses. Under favorable circumstances, therefore, it can be used to keep sugar-cane fields, cornfields, golf courses or lawns free from most common weeds without laborious hoeing or weeding. Recent experiments indicate that in the plants affected by 2,4-D there is a temporary sharp increase in the rate of metabolism. The sprayed plant is not only injured where the chemical comes in contact with it, but is stimulated to burn up its reserve food supply. As a consequence it starves to death. In smaller concentrations 2,4-D can also be used for most of the applications of auxins previously mentioned. It can even cure—by its lethal action in another area of the plant kingdom—the fungus infection athlete's foot. In fact, 2,4-D well illustrates the wide variety of responses that auxins can elicit from plants.

THE great versatility of this hormone was graphically described in an account of a series of experiments by J. W. Mitchell in the *Yearbook of Agriculture 1943-1947*:

"For instance, if only a speck, about one millionth of an ounce, of 2,4-D is put on one side of the stem of a bean seedling, the cells along the treated side grow faster than those on the untreated side and the plant will bend sharply in a direction away from the treated surface. If, however, about 2,000 times that amount of 2,4-D (about as much of the powder as can be held on an eighth of an inch of the flat end of a toothpick) is mixed with a little lanolin and the mixture is rubbed on a tender section of the stem, the plant responds differently. Food materials within the plant are moved from other parts of the stem, and possibly from some of the leaves, into the treated section, where many new cells are formed. The new cells finally become organized and arranged so that they form new roots inside the stem. The young roots, called root primordia, later push their way to the outer surface of the stem, and if that part of the stem is covered with moist soil the primordia will grow out into it and function as ordinary roots do in supplying the plant with water and nutrients.

"If, on the other hand, the above-ground parts of the plant are sprayed or dusted with 2,4-D, the response is yet different, for leaf growth ceases, the rate of respiration of the plant is increased, and its reserve food materials are broken down and subsequently burned up. As a result the plant generally dies one to three weeks after treatment, or the length of time required for its reserve food materials to be depleted."

We can see now that while the activities of plant hormones parallel those in animals up to a point, the parallel is not complete. The auxins seem to be more general and versatile in their effects. Whereas an animal hormone is likely to control only a single process or reaction, an auxin may influence a plant in many different ways, at least so far as the physical effects are observable. Sometimes it stimulates growth; under other conditions it retards growth. Sometimes it induces a tumor. Sometimes it kills the entire plant. Such observations lead with increasing clarity to the conclusion that the auxins must influence some basic general cellular process, and that the result of this influence may be expressed in a variety of ways, depending on the nature and age of the tissue, on the availability of other interacting substances, and on the external and internal conditions.

MANY investigators have concerned themselves with determining how the influence is effected and what reactions are involved; for to understand the mechanism regulating the growth and development of plants would indeed be a step toward understanding life itself. Theories have been proposed, of course, but they are little more than guides for further research, since none is supported by a sufficient body of facts and observations to be accepted as an explanation. Because the auxins affect the growth of plants in such small concentrations, it is widely believed that the auxins must play some role in an enzyme system, either directly, for example as coenzymes, or indirectly through chemical mediation. Although the identity of the enzyme involved in the response to auxins has not yet been established, it is to be hoped that work now in progress will eventually yield the long-sought explanation.

Meanwhile the chemical revolution in agriculture continues and the prospect of regulating the rate and pattern of plant growth by auxins gives promise of a new epoch of abundance through a hitherto unhoped-for control over nature.

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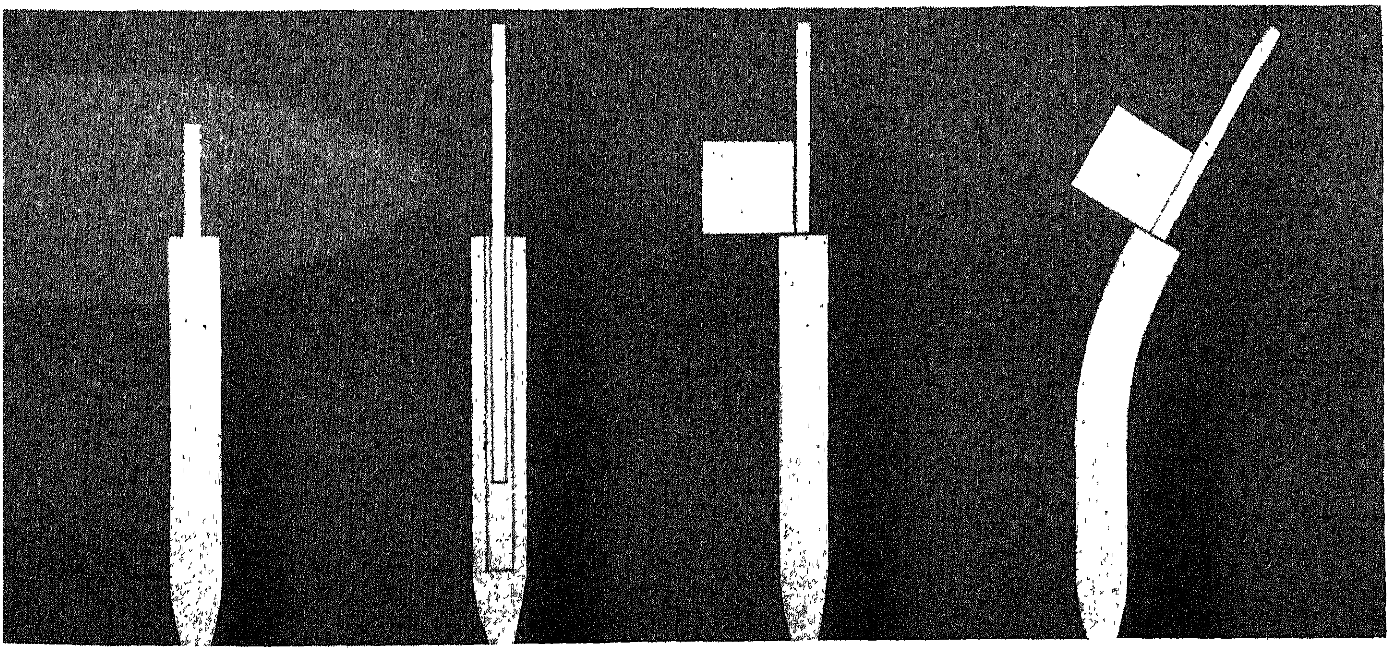


leaf grows out. In fourth and fifth an outer section is cut off, leaving leaf. In sixth the leaf is gently pulled loose. In seventh the agar block is mounted. In last drawing the hormone in block causes the seedling to bend.

The Nature of Dreams

Do they express the dreamer's irrational strivings, as Freud contended? Not necessarily, says a modern analyst, suggesting a new interpretation of them

by Erich Fromm

SIGMUND FREUD'S theory of dreams was part of his theory of man. He assumed that man in the course of his growth is forced to repress evil strivings—egocentricity, destructiveness, irrationality—in order to adapt himself to the requirements of social life. He does so, said Freud, partly by turning his asocial strivings into socially useful ones—a process which Freud interpreted as either "sublimation" or "reaction formation." Successful "sublimation" is exemplified by the surgeon who has turned his original sadistic strivings into a socially useful activity. An example of successful "reaction formation" is that of a humanitarian who has developed great kindness in combatting his destructive potentialities. The best in man, according to Freud, is rooted in his worst.

When we are asleep, Freud reasoned, we relax the effort that normally restrains the criminal we are at bottom. Our dream life is the refuge, as it were, where we recover from the heavy burden of our culture and are free to satisfy repressed infantile strivings. Yet even in sleep the internal censor's attention is only relaxed, not entirely dismissed. To deceive him, we dream in a kind of secret code. The real meaning of the dream can be understood only if the code is deciphered. This process of deciphering is what Freud called the interpretation of dreams

Freud's theory of dreams shocked psychologists and was denounced by many as unscientific. Most of his followers have defended it fanatically, though some, accepting its heavy content of truth, came to consider it one-sided. Carl Gustav Jung, who became the leader of this group, tended increasingly to emphasize the "higher" aspects of dreams just as one-sidedly as Freud had emphasized the "lower." Where Freud had found in dreams only irrational infantile strivings, Jung saw only expressions of moral or religious experiences, which he interpreted as outgrowths of racially inherited religious and metaphysical ideas.

If a man saw in his dream a woman whose features were unknown to him, Freud would assume that this woman represented his mother, that the infantile sexual attachment to the mother, repressed in the conscious state, was satisfied in the dream Freud argued that in the dream she remained unknown to the dreamer in order to fool the censor. Relating this longing for the mother to the recent experiences of the dreamer, the analyst sought the hidden incestuous aspects in the dreamer's relationship to a woman with whom he may recently have fallen in love Jung, on the other hand, tended to interpret the unknown woman as the image of the "unconscious," and also as a symbol of the feminine aspects in the male dreamer's personality

Had Jung been less concerned with creating another school, and less fascinated by irrational racialism, his departure from Freud's dogmatism could have avoided the blind alley into which it ultimately led. As matters stand, a constructive revision of Freud's theory of dreams must pick up the thread where it was left before Jung's and other schools of psychoanalysis were formed.

WE MAY begin with Aristotle's definition of dreams, quoted but not accepted by Freud. Dreams are expressions of any kind of mental activity under the condition of sleep. The distinctive quality of dreams, then, is not a particular area of experience—neither Freud's "infantile wishes" nor Jung's "true picture of the subjective state"—but the effect of the condition of sleep upon our mode of experiencing.

Physiologically, sleep is a condition of chemical regeneration of the organism. Energy is restored while physical activity and even sensory perception are almost entirely discontinued. Sleep suspends the main function of waking life: reacting to reality by perception and action. This difference between the biological functions of waking and of sleeping is, in fact, a difference between two states of existence In the waking state, thoughts or feelings respond primarily to challenge—the challenge of mastering our environment, changing it, defending ourselves against it. The primary task of waking man is survival; this means, essentially, that he must think in terms of time and space, and that his thoughts are subject to the logical laws which are necessary for action.

During sleep the frame of reference changes radically. While we sleep we are not concerned with bending the outside world to our purposes. We are helpless—but we are also free. We are free from the burden of work, from the task of attack or defense, from watching and mastering reality. We live in an inner world concerned exclusively with ourselves

In sleep the realm of necessity has given way to the realm of freedom where "I" am the only system to which thoughts and feelings refer. In a dream the grief I experienced 10 years ago may be just as strong now, and I may hate a person on the other side of the globe as intensely as if he stood beside me. Sleep experience need not pay attention to qualities that are important in coping with reality. If I feel, for instance, that a person is a coward, I may dream that he has changed into a chicken. This change is illogical in terms of my orientation to outside reality, but logical in terms of what I feel about the person. Sleep experience, therefore, is not lacking in logic, but is subject to a special logic of its own, which is entirely valid in that particular experiential state.

The "unconscious" is unconscious only in relation to the "normal" state of activity. When we call it "unconscious," we really say only that it is an experience alien to the frame of mind which exists while we act, it is then felt as a ghostlike, intrusive element, hard to get hold of and to remember. But the day world is as unconscious in our sleep experience as the night world is in our waking experience.

From what has been said so far it follows that the concepts "conscious" and "unconscious" are to be understood relative to the sleeping and waking states respectively. As an old Chinese poet put it: "I dreamed that I am a butterfly, now I do not know, am I a man who dreamed he was a butterfly or am I a butterfly who dreams it is a man." In the waking state of action those experiences

which feel real in the dream are "unconscious." But when we are asleep and no longer preoccupied with action but with self-experience, the waking experience is "unconscious" and sometimes it is a hard struggle to chase away the sleep world and to convince oneself of the reality of the waking world.

It is true that even in the waking state of existence, thinking and feeling are not entirely subject to the limitations of time and space. Our creative imagination permits us to think about past and future objects as if they were present, and of distant objects as if they were before our eyes. It could therefore be argued that the absence of the space-time system is not characteristic of sleep existence in contradistinction to waking existence, but of thinking and feeling in contradistinction to acting. Here it becomes necessary to clarify an essential point.

We must distinguish between the *contents* of thought processes and the *logical categories* employed in thinking. While it is true that the contents of our waking thoughts are not subject to limitations of space and time, the logical categories of thinking are those of the space-time logic. I can, for instance, think of my father, and state that his attitude in a certain situation is identical with mine; this statement is logically correct. If I state, on the other hand, "I am my father," the statement is "illogical" because it is not conceived in reference to the physical world. The sentence is logical, however, in a purely experiential realm: it expresses the experience of intense closeness to my father. When I have a feeling in the waking state with regard to a person whom I have not seen for 20 years, I remain aware of the fact that the person is not present. But if I dream about the person, my feeling deals with the person as if he or she were present. Even to say "as if he were present" is to express the feeling in logical waking-life concepts. In sleep existence there is no "as if", the person is present. (It is true, however, that sleep is not completely free from action concepts, as proved by the fact that sometimes we think in our dream that what we dream cannot really be so.)

The experiential mode of thought occurs in other forms of dissociation besides dreams—in the hypnotic trance, in psychoses, in early infantile experience, and possibly in primitive thinking. And there is, of course, the state of intense mystical contemplation, wherein attention is withdrawn completely from the outside world as a potential field of action, and is completely focused on self-experience although the person remains awake. The mystic, indeed, considers this state to be the highest awareness. The language employed in such a state of contemplation follows the experiential logic of the dream, not the action logic of "normal" thinking.

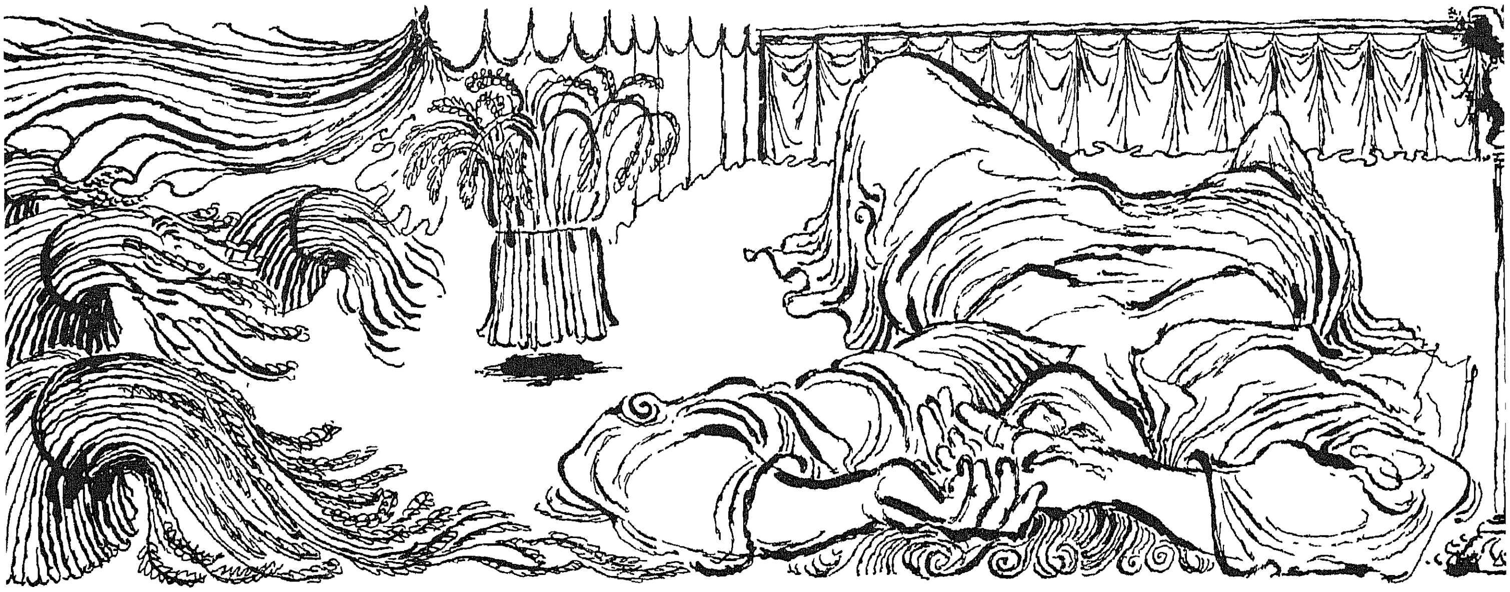
So the sleep existence, it seems, is only the extreme case of a purely contemplative experience, which can also be established by a waking person if he focuses on his inner experience. Symbolic language employing experiential logic is one mode of human expression—just as valid and rational as our "normal" logic, and different from it only as to the systems of reference. These systems, in turn, are determined by the total orientation of the culture. Cultures in which the emphasis is on self-experience, such as those of the East, or some "primitive" cultures where mastery of nature is little developed, give great scope to this symbolic language. In modern Western culture, almost exclusively focused on activity in the sense of mastery over nature, the comprehension of symbolic language has atrophied. Dreams are remnants of a legitimate mode of human expression, once well known, now looked upon as if they were undecipherable hieroglyphs.

IT is the peculiarity of dreams that inner experiences are expressed as if they were sensory experiences, subjective states as if they were actions dealing with external reality. This interchange between the two modes of experience is the very essence of symbols, and particularly of the dream symbol. While the body is inactive and the senses shut down, the inner experience makes use of the dormant faculties of sensory reaction.

A forceful illustration of the dream's symbolic language is the story of Jonah. God commanded the prophet to help the people of Nineveh to repent of their sin and so to save them. But Jonah is a man of stern justice rather than of mercy; he declines to feel responsible for sinners and attempts to escape from his mission. He boards a ship. A storm comes up.

SIGMUND FREUD, whose interpretation of dreams formed a keystone of his psychology, argued that they were symbolic expressions of man's repressed impulses.

CARL GUSTAV JUNG, a disciple who broke with Freud, thought that dreams were idealistic expressions of mankind's highest moral and religious experiences.



FAMOUS DREAM OF JOSEPH in the Bible is here pictured in drawings which show the sheaves of grain (*left*) and the sun, moon and stars making obeisance to him in his dream. Freud's interpretation would be that the dream expressed Joseph's feeling of superiority to his father and brothers. But the events he

Jonah goes into the hold of the ship and falls into a deep sleep. The sailors believe that God sent the storm because of Jonah and throw him into the sea. He is swallowed by a whale and stays inside the animal for several days.

The central theme of this symbolic, dreamlike story is Jonah's desire for complete seclusion and irresponsibility—a position which at first was meant to save him from his mission, but eventually is turned into an unbearable, prisonlike existence. The ship, the sleep, the ocean, the whale's belly—all are different symbols of that one state of existence. They follow each other in time and space, but they stand for growing intensity of a feeling—the feeling of seclusion and protection. Being inside the whale has brought this experience to such a final intensity that Jonah cannot stand it any longer; he turns to God again; he desires to be freed, to go on with his mission.

So far we have been concerned with the mode of expression and the particular logic of dreams resulting from the peculiar condition of sleep. We must now turn to the question in what respect the state of sleep also determines the *content* of dreams. According to Freud it does so in a specific way. Culture, in his view, suppresses our primitive—bad—instincts and the sublimation and reaction formation springing from this suppression are the very essence of civilized life. Quite logically, then, in his view, dreams must bring out our worst, since in our sleep we are free—though not entirely—from cultural pressure.

There can be no doubt that many dreams express the fulfillment of irrational, asocial and immoral wishes which we repress successfully during the waking state. When we are asleep and incapable of action it becomes safe to indulge in hallucinatory satisfaction of our lowest impulses. But the influence of culture is by no means as one-sidedly beneficial as Freud assumed. We are often more intelligent, wiser and more moral in our sleep than in waking life. The reason for this is the ambiguous character of our social reality. In mastering this reality we develop our faculties of observation, intelligence and reason; but we are also stultified by incessant propaganda, threats, ideologies and cultural "noise" that paralyze some of our most precious intellectual and moral functions. In fact, so much of what we think and feel is in response to these hypnotic influences that one may well wonder to what extent our waking experience is "ours." In sleep, no longer exposed to the noise of culture, we become awake to what we really feel and think. The genuine self can talk; it is often more intelligent and more decent than the pseudo self which seems to be "we" when we are awake.

My conclusion, then, is that we may expect to find true insights and important value judgments expressed in our dreams, as well as immoral, irrational wishes. We may even find in them reliable predictions, based on a correct appreciation of the intensity and the direction of forces operating in ourselves and in others. Both Freud's emphasis on the "low" and Jung's emphasis on the "high" aspect of dream content are dogmatic restrictions. Only if it is recognized that dreams can express either side of a dreamer's nature is the way cleared for a real understanding of them.

The following examples illustrate the alternative interpretations that can be given to the same dream. The dreamer sees himself naked in the presence of strangers and feels ashamed but powerless to alter the painful situation. Freud said that this dream represented an infantile exhibitionistic impulse still alive in the adult. During sleep this impulse comes to the fore and finds its fulfillment in the dream; the dreamer's mature personality, not entirely silenced, reacts with shame and fear to the very wishes of his infantile self.

No doubt many nakedness dreams are to be so understood. But others must be interpreted differently. Nakedness is not necessarily an expression of sexual exhibitionism; it can also symbolize the true self of a person, free from pretense and make-believe. A person who dreams of himself as being naked in a well-dressed group may give symbolic expression to his wish to be honest, to be more himself, not to be the conformist who wants to please everybody. And his embarrassment in the dream is the same embarrassment he would feel in waking, too, whenever he tried to discard his dependence on other people's opinions.

According to the orthodox Freudian interpretation, the nakedness dream's essential impulse is an infantile sexual desire; in the alternative interpretation, it is a rational wish, rooted in the most mature part of the dreamer's personality. But if so, why should it be disguised in dream symbolism? Why should we repress some of our very best impulses? The answer is that in our culture people are no less ashamed of their best strivings than of their worst. Generosity is suspected as "foolish," honesty as "naive," integrity as "not practical." While one tendency within our complex culture presents these qualities as virtues, another stigmatizes them as "idealistic dreams." Consequently wishes motivated by such virtues often live an underground existence together with wishes rooted in our vices. To mistake rational wishes of the dreamer for expressions of irrational strivings makes it impossible for him to recognize positive goals which he has set himself. Yet to see in every dream an ideal or pro-

dreamed of actually came true, and the author suggests that Joseph's vision in sleep revealed true insight, picturing a real superiority that Joseph could not admit in the conscious state for fear of social disapproval. Dreams, in the author's opinion, may contain reliable predictions, based on a more accurate understanding.

found religious symbol is just as fallacious. Whether a dream is to be understood as an expression of the rational or the irrational side in ourselves can be determined only by a full investigation of the individual case—by knowing the dreamer's character, his associations with the dream elements, the problems he was concerned with before he fell asleep.

The following dream is an example of unconscious insight and moral judgment: A man has visited X, a widely known figure whose kindness and wisdom are praised by everybody. He was properly impressed by the admirable man. The same night he dreams of X, who now has a cruel face and tries to swindle a poor old woman out of her last dollar. He remembers this dream the next day, is quite surprised, and wonders why the dream picture of X differs so completely from the "real" picture of the day before. Suddenly he is struck by the recollection that his instinctive reaction to X had been one of intense antipathy—but so fleeting had this first reaction been that he was not aware of it at the time of the visit. Actually his antipathy was his real insight into X's character. It was silenced at once by the conventional picture of X: the "noise" had drowned the dreamer's real judgment, which awoke when he was asleep.

If this dream were understood in Freud's terms, the subject would accuse himself of unconscious hostility and, having discovered his own wickedness, would be all the more prone to accept the conventional picture of X. If, on the other hand, the interpreter assumed that dreams unerringly express the "real" judgment, the dreamer might accept his dream as evidence against X, and act accordingly, though it may indeed have expressed only the dreamer's own hostility. Which interpretation is correct can be found only in an appraisal of the dreamer's total situation.

One of the best-known dreams of prediction is Joseph's dream, reported in the Bible. He dreamed that the sun, moon and stars were making obeisance to him. His brothers, hearing of the dream, did not need the help of an expert to understand that the dream expressed a feeling of superiority over his parents and brothers. It certainly can be argued that the infantile rivalry with father and brothers was the root of the dream (which would be Freud's interpretation). But what Joseph saw in the dream later came true; the dream indeed predicted future events. And Joseph was able to make such a prediction because he sensed his exceptional gifts, which made him actually superior to the other members of his family; but the conceited character of such insight made it impossible for him to be aware of his superiority—except under the condition of sleep.

WHEN we dream we speak a language which is also employed in some of the most significant documents of culture: in myths, in fairy tales and art, recently in novels like Franz Kafka's This language is the only universal language common to all races and all times. It is the same language in the oldest myths as in the dreams every one of us has today. Moreover, it is a language which often expresses inner experiences, wishes, fears, judgments and insights with much greater precision and fullness than our ordinary language is capable of. Yet symbolic language is a forgotten language, considered by most as nonsensical or unimportant. This ignorance not only prevents us from understanding the wisdom expressed in myths but also from being in touch with a significant part of ourselves. "Dreams which are not understood are like letters which are not opened," says the Talmud, and this statement is undeniably true.

Why, then, do we not teach the understanding of this forgotten language as a subject in the curriculum of higher education?

True, there are dreams so difficult and complicated that it requires a psychologist of great knowledge and technical skill to understand them; and sometimes even the expert will fail. But is this so different from the study of languages, of mathematics, of physics? Liberal education, in general, only lays the foundations for more specialized skills which the student later develops for himself. The analogy between teaching dream interpretation and teaching languages is particularly close, not only because dream language is a sort of "foreign language" but also because the results of teaching are similar. No student succeeds in mastering a foreign language without specialized study; but even an average undergraduate is capable of understanding syntax and grammar.

For a number of years I have been teaching dream interpretation not only to graduate students of psychoanalysis but also to undergraduates at Bennington College. The results, at least to my satisfaction, compare with the results of teaching any other subject matter to the same group of students. Remarkable achievements have been rare in this as in any other field; the minimum achievements have not been lower. The aim is to help the student to understand an unknown language in which he expresses important aspects of his own personality, and also to understand a mode of expression in which mankind has expressed some of its most significant ideas.

Erich Fromm is author of the books Man for Himself *and* Escape from Freedom.

Living Records of the Ice Age

The missing snakes of Ireland, the peat of the English Channel and the fishes of Great Salt Lake are among the biogeographer's clues to the events of the Pleistocene

by Edward S. Deevey, Jr.

WHY are there no snakes in Ireland? Popular legend says that St. Patrick drove them out. Science has a less romantic answer, but the popular one is not devoid of scientific significance, for whoever thought of it first must have recognized a real problem. That is, he must have realized that snakes *ought* to occur in Ireland, and concluded that they once did. There are no land snakes in Hawaii either, but I doubt that Hawaiian folklore has found it necessary to invent a story to account for the fact. On an oceanic island, separated from the nearest land by thousands of miles of deep water, one does not expect to find certain kinds of continental animals. But Ireland stands in relatively shallow water and must once have been part of the Continent. It belongs to Europe, though no longer to the British Empire.

Great Britain, which is just as much an island as Ireland, has at least three kinds of native snakes. Moreover, Ireland does not entirely lack reptiles and amphibians; its inhabitants include a species of salamander, two tailless amphibians and a lizard, all of which also live in Great Britain. Clearly, if someone did not chase the snakes from the Ould Sod, some other sort of special explanation is called for.

This kind of question has an endless fascination for biologists. Usually it can be answered, if it is answerable at all, only by appeal to the geologist, who may explain the distribution of animals in terms of the rise and fall of seas and land masses, the invasion of glaciers, changes of climate, and so on. The present range of a plant or animal species is the product of past as well as present geographic conditions, avenues of dispersal may once have existed where there are barriers now and *vice versa*, and the geologist will know about past conditions if anyone does. I shall be concerned to show, however, that circumstances are sometimes reversed, and the biogeographer, dealing with the existing distribution of animals and plants, is able to aid the geologist.

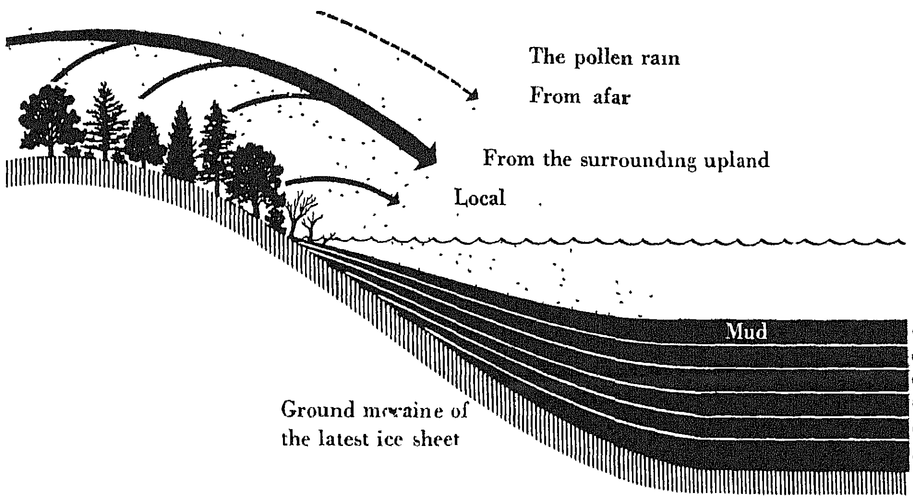
The absence of snakes, and of many other animals that might be expected to live in Ireland, is a direct outcome of the Pleistocene geography of the British Isles. The matter has been summarized by Hallam Movius of Harvard University, who, interestingly enough, is not a geologist but a student of paleolithic archaeology. As a member of the Harvard Irish Survey, sometimes known as "Harvard's investigation of the origins of the Boston police," he had good reason to attempt a synthesis of the problems of Britain during the Pleistocene.

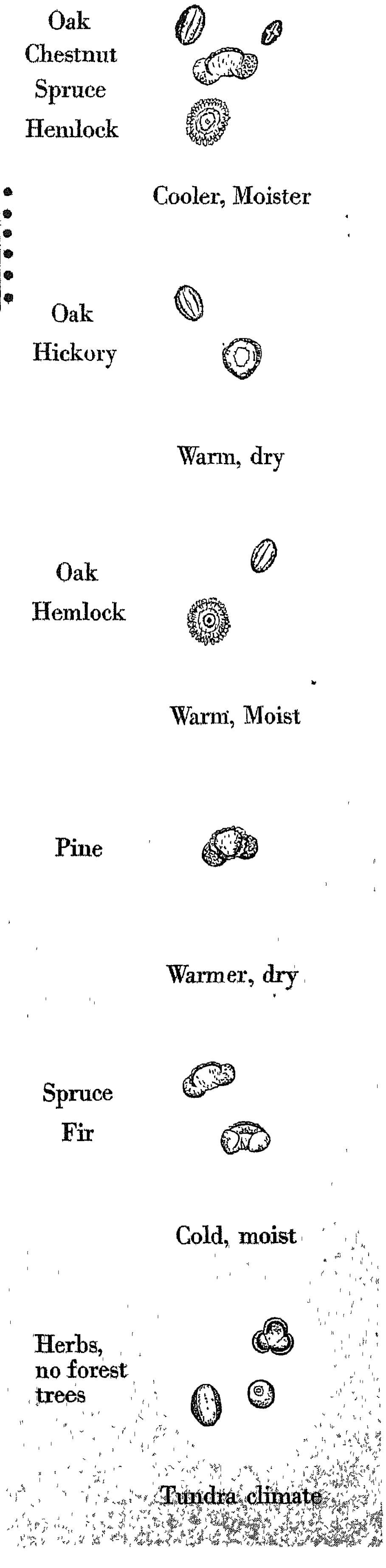
Of the four major glacial ages into which the Pleistocene epoch is divided, we are sure that the latest, during its earliest part, saw all of Ireland and nearly all of Britain blanketed by ice. This glacial advance was followed by retreat and a time of genial climate. How far back toward Scotland the ice withdrew is not certainly known, but lime and holly grew at Kirmington in Yorkshire during the interval, and Aurignacian man, famous for his paintings in the caves of southern France, was able to push north as far as Yorkshire. After this comparatively warm episode the ice sheets advanced again as far as the English Midlands, Wales, and in Ireland as far as Tipperary.

Whether any of the animals and plants now found in Britain have lived there continuously since the last interglacial age is uncertain. It seems doubtful that more than a few of the hardiest—those now living in the highest parts of Ireland and Scotland—could have survived through the last glaciation. At any rate, the great majority of the present flora and fauna must have immigrated more recently. At the climax of the last glacial age England and Ireland were joined to the European Continent. This came about because so large a fraction of the Earth's supply of water was frozen and piled on the land in the ice sheets of Europe and North America that the sea level was lowered, probably by about 300 feet. But at this glacial time the British Isles would scarcely have offered a desirable goal for the immigration of animals from Europe.

THE postglacial arrival of the seas at their present level was the result of two independent and partly opposed processes: the restoration of water to the oceans, and the recovery of the Earth's crust from its crushing load of ice. The latter, of course, was confined to the glaciated regions, while the former was world-wide in its effects. To a considerable extent the clarification of this complex history in Britain has depended on a time scale devised by biologists. This is the chronology based on analysis of ancient deposits of pollen (*see chart on opposite page*). It enables the British geographers to say that though the land is still rebounding, the sea itself had nearly finished its rise by the end of the Boreal phase of postglacial time. This was an episode of warm and comparatively dry climate in western Europe, when Middle Stone Age man was adapting his hunting culture to the first postglacial forests. In early Boreal time man and many animals and plants were able to cross dry-shod from France into England. By the end of the phase or shortly thereafter the sea had risen about 150 feet, and the English Channel had come into existence.

It is only by the grace of a remarkable geological accident that this sequence of events has been determined. From the Dogger Bank and other places in the North Sea, down to a depth of 162 feet, there have been dredged up deposits of





CLIMATIC CHRONOLOGY of eastern North America may be determined by boring into the bottom of lakes. The pollen from the plants of each period lies in a layer. The species of plants may be identified by the pollen. The climate of the period is then inferred from the plants that lived in it.

peat. Now peat is a fresh-water deposit, a fact which is confirmed in this instance by finding fossils of beetles in it. The peat cannot have been picked up from the land and redeposited by the waves of the North Sea, for there is too much of it, and it is too coherent, being in all respects like peat from swamps. It must lie on an old land surface. By the depth of the salt water over it we can measure the drowning, and the pollen that it contains establishes its age as Boreal.

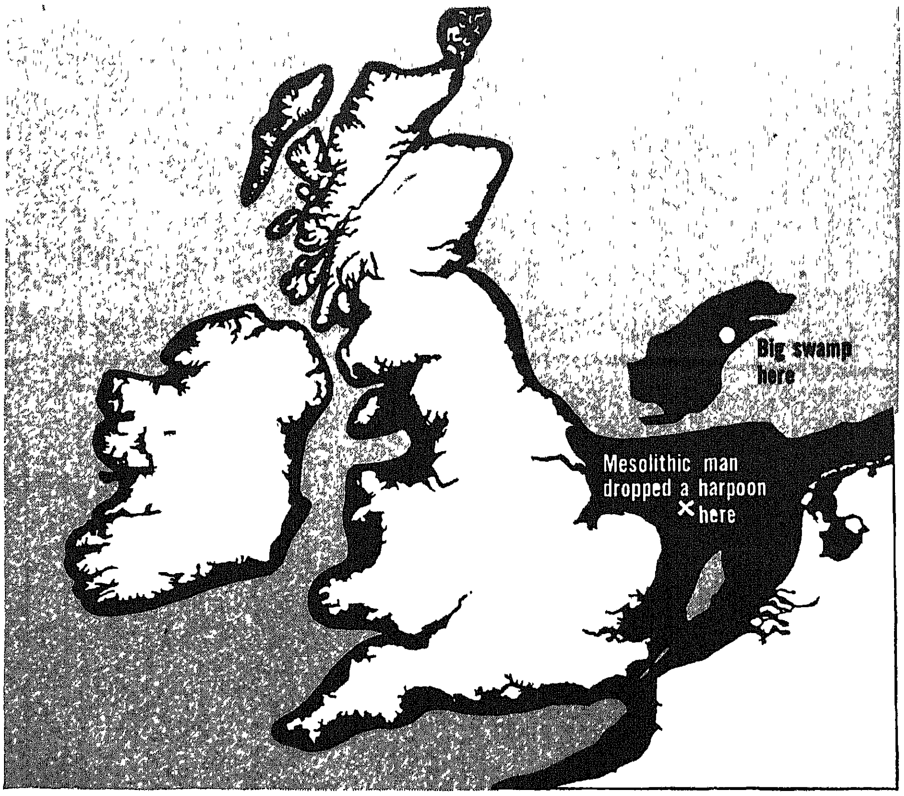
The luck of the Irish geologists has not been so great. The bottom of the Irish Sea has apparently been much modified by marine erosion since its formation, and it offers no means for a geological determination of how long Ireland remained joined to England. The most one can say is that, as the water is deeper there than in the English Channel, it looks as though Ireland was severed from England before England was separated from the mainland.

This is just what biogeographers have maintained. The land animals of Ireland are fairly typical of an island that formerly was in direct communication with a neighboring continent. The island possesses a rich fauna, containing many animals, such as the frog, the salamander, the hedgehog, the pygmy shrew and the stoat, that seem to have required a land connection for their immigration. If only a few of these were present, one might put their occurrence down as a rare and unexpected instance of dispersal over water. But the Irish list is too balanced and representative to have been the result of a series of such casual migrations

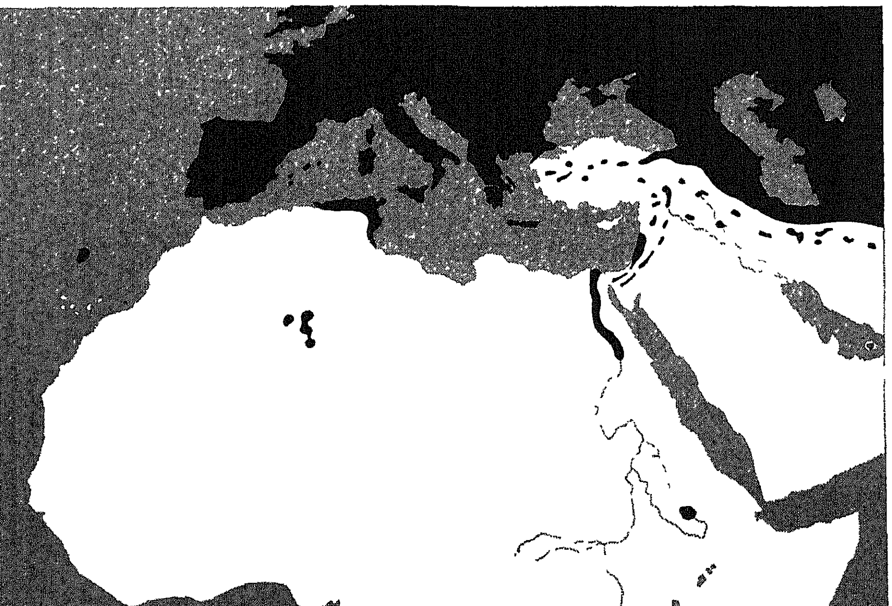
Yet when comparison is made with England, we see that the species missing from Ireland are as suggestive as those that are present. Ireland lacks the common English meadow mouse, or any other member of the vole subfamily of rodents St. Patrick's curious prejudice seems also to have extended to the brown hare, the common shrew, the mole and the weasel, not to mention the dormouse and the yellow-necked field mouse. Perhaps because of the absence of competition with these common European and English types, certain Irish species have undergone considerable evolution in their proud Hibernian isolation, and they are now distinct from their representatives and presumed ancestors in Europe. Examples are the Irish hare and the Irish stoat.

These facts can mean only one thing: that a few early postglacial immigrants from Europe managed to reach Ireland over the land bridge via Great Britain, only to be cut off by the postglacial rise of sea level. England and Scotland, which maintained direct connection with the Continent longer, received later waves of invasion by land animals.

The same type of problem as that of Britain and Ireland has been studied by biogeographic methods on the other side of the world, in the Philippines. The three islands of Negros, Panay, and Masbate, collectively called Visaya by Philippine biogeographers, stand together on a submerged shelf less than 160 feet deep. A lowering of sea level by that amount would make them all one island. They are separated from the nearby island of Cebu by a strait 320 feet deep. There are 32 kinds of nonmigratory birds restricted to Visaya, and 12 different kinds to Cebu. It does not surprise ornithologists to find birds so sedentary that they do not fly from one island to another. The significant fact is that the 32 endemic subspecies are common to the three islands joined together by the 160-foot depth contour, yet are lacking from nearby Cebu. Evidently the last glacial lowering of sea level was sufficient to permit free migration by land



PLEISTOCENE MAP shows that Ireland and England were separated from each other at a time when England was still joined to the Continent. Pleistocene coastline is in black; present coastline is in white. The snakes that migrated from the Continent presumably could get no farther than England.



PRESENT DISTRIBUTION of the waterbug *Corixa* is indicated by black areas in Europe, Africa and Asia Minor. Islands of *Corixa* in Africa have been interpreted by the Yale University zoologist G. Evelyn Hutchinson as remnants of pluvial period when Sahara was easier for the species to cross.

birds among the three islands of Visaya, but not great enough for interchange with the bird populations of Cebu. In other words, the lowering of the level was more than 160 feet but less than 320 feet. Most estimates of the worldwide fall of the sea level in the last glacial age range from 230 to 335 feet, so the agreement is encouragingly close.

ANOTHER dramatic study of Pleistocene geography has been based on the distribution of fresh-water fishes in the Great Basin of the western U.S. This subject has been investigated most recently by Carl L. Hubbs of the Scripps Institution of Oceanography and Robert R. Miller of the University of Michigan. Here the problem is not one of changes of land and sea but of cycles of rainy, or "pluvial," climate. The deserts of the world, including the middle-latitude deserts of North and South America, Asia, and North and South Africa, experienced pluvial climates during glacial ages of the Pleistocene. The deserts literally blossomed like the rose. Great lakes were formed, fed by many rivers. The Great Salt Lake, to name an example, is a pitiful remnant of its pluvial ancestor, Lake Bonneville.

To stand amid sagebrush and saltbush on the floor of a Pleistocene lake, with its ancient shore lines clearly visible on the surrounding mountains, is a stirring experience for a geologist. It is even more exciting for a biologist, in the same circumstances, to see at his feet a tiny water hole—a spring or perhaps a fragment of a stream that flows only during infrequent rainstorms—and to realize that fishes in the water are the last survivors of a Pleistocene fauna.

Geographic isolation is a powerful factor in the formation of species. If the isolation is of long standing, evolutionary divergence proceeds so far that the distribution of existing species becomes a puzzle to the geographer. But where the isolation is the result of geographic changes since the last pluvial age, the finding of fishes of the same species in separate basins in a region demonstrates that the waters were once connected. In the western Nevada of Pleistocene times there was a large body of water, pluvial Lake Lahontan. Its only appreciable modern descendant is Pyramid Lake, but there are many dry or nearly dry basins in the area, such as Big Washoe Lake and Carson Sink, that were formerly either part of Lake Lahontan or held lakes tributary to it. Some of these basins still have fishes in streams and springs, and they invariably belong to the Lahontan fauna, as we can reconstruct it from the present species of Pyramid Lake and Lake Tahoe.

Sometimes the fish distribution points conclusively to the former connection of waters where the physiographic evidence is inadequate. More often, per-

haps, the biologist is merely able to confirm the conclusions of the geologist. Physiographic data are more critical than biogeographic, and it would be idle to deny it. But when geologists showed that Pyramid Lake is too fresh to have existed in its present basin longer than about 4,000 years, and claimed that it must have dried up during an arid postpluvial episode that ended about that long ago, biologists were quick to point out that this conclusion is incompatible with the existence of well-defined endemic fishes (a salmon and a sucker) in Pyramid Lake. These can only be Lahontan types, and therefore date back at least to the last pluvial age, 15,000 years or more ago. There must be some explanation other than youth for the continuing freshness of the lake. For instance, it might once have had an outlet that carried off the salts delivered by rivers, and most of the salts delivered in the past 15,000 years or so since the lake was isolated could have been deposited elsewhere by evaporation. And the geologists, reconsidering, admitted that such could have been the case, and that the Black Rock Desert, to the north, evidently received and then concentrated the overflow.

In Africa, biogeography suggests that the Sahara and other great deserts also had a rainy Pleistocene history. Some geologists deny that pluvial ages existed in equatorial Africa, but it is clear from the biologic data that a great deal of migration of animals and plants requiring a moist, temperate climate took place across regions that are deserts today, and this can only mean that the deserts had pluvial episodes. The evidence of the leakage of such species across the now arid regions is especially clear in the present distribution of aquatic animals and plants. The waterbug genus *Corixa,* which is an inhabitant of temperate Europe, has an outlying station in Lake Naivasha in the eastern Rift Valley of East Africa. In French Guinea on the West African coast lives a salamander that apparently migrated from Europe, it is the only salamander below the Tropic of Cancer in the Old World The range of some species of birds, now divided between Abyssinia and the mountains of East Africa, shows that there was once a wider distribution of forests on the African plateau.

Though biogeography has its triumphs, it also has its failures. A method that places so high a premium on scientific imagination is peculiarly liable to error. In general, the farther back in geologic time a biogeographic theory is pushed, the more likely it is to be false. Some restorations of past geography, notably certain land bridges erected on insufficient evidence, have turned out to be monumentally wrong. Even in Pleistocene biogeography, where we deal with events that occurred only yesterday, geologically speaking, it is exceedingly easy to be mistaken.

One of the most famous theories erected on biologic evidence is the nunatak hypothesis, proposed in 1925 by Merritt L. Fernald of Harvard University. In the mountains of the Gaspé Peninsula, Newfoundland and Labrador, the higher peaks, in the opinion of some geologists, projected above the ice during the ice age, as some do in Greenland and Antarctica today. The Eskimo word *nunatak* is used for such bare peaks. Fernald argued that many plants now found in eastern North America are older than the last glacial age, and that they survived the glaciation by taking refuge on nunataks. There is no doubt that certain plants could have done so, for they have been collected on modern nunataks in Greenland. But irises and lady's-slippers do not belong on such a list, and in applying his theory of glacial survival to warmth-loving types Fernald seems to have proved too much.

The basis of his argument was the occurrence, in the highlands around the Gulf of St. Lawrence, of many plants of peculiar distribution. Some of them, confined to patches a few acres in extent, have their only close relatives in the mountains of the West. In other cases even the same species is found in the Rocky Mountains and in Eastern colonies 2,000 miles away. Because the distance of these colonies from the main range in the Rockies is so great, and because so many of these plants have produced new varieties and species, their Eastern isolation implies an origin at least as old as the last glacial age. Since many of them are narrowly localized and evidently incapable of spreading, Fernald thought it impossible that they could have reached their present localities by migration from the Rockies in the relatively short space of postglacial time. But so many plants have this sort of distribution that Fernald's hypothesis cast doubt on the view that eastern North America was extensively glaciated.

Geologists who have re-examined the region with the nunatak hypothesis in mind have concluded that their predecessors relied too heavily on negative evidence in supposing that mountain peaks were left uncovered by the ice sheet. The frost action characteristic of mountain climates tends to destroy the indications of former glaciation that are customarily looked for. Striae are softened or obliterated, glacially modeled bedrock is blanketed by rubble, and it is difficult to distinguish glacial till from the bouldery material carried by mudflows. Occurrence of foreign stones in such a deposit is decisive evidence of an overriding ice sheet, but this is the sort of evidence that was usually missed by early geologic reconnaissance. Such boulders were found on the second try. Since we know now that active ice moved over the tops of some of the supposed nunataks, the plants must have had an uncomfortable time.

As one of the skeptical geologists has remarked, it seems easier for a plant to reach the top of a mountain in postglacial time than for a foreign boulder to do so. The biogeographic evidence, in other words, cannot be conclusive. If there were nunataks projecting above the Pleistocene ice, a few of the hardiest species presumably lived on them, though not exclusively there. It is granted that some of the St. Lawrence plants may antedate the last glacial age, but so, obviously, do most other plants that were pushed south by an ice sheet and returned on its retreat. The present flora of the St. Lawrence region must have survived the latest glaciation in refuges south of the ice, and subsequently migrated north to its present position. The narrowly localized distribution of many species is not a proof of old age, for in some cases it is the result of a preference for a particular type of soil, while in others it is a sign of youth. The separation of the eastern and western populations is most simply explained by the hypothesis that the formerly continuous range of the plants was broken by glaciation of the continental interior.

Many biogeographers have made the mistake of underestimating the postglacial and modern powers of dispersal of organisms. But the fair-minded geologist will not reject all biogeographic data on that account. For the solution of certain types of problems, especially the restoration of Pleistocene land connections and stream connections, the strictly geologic data are likely to be inadequate, and the present distribution of animals and plants can be extremely helpful. Of course, one would always prefer that the deductions from the existing distribution be documented by the distribution of fossils in a clear stratigraphic context. Yet such documentation is all too rare, and we have to work with the evidence we have.

The geologist can remind himself that geology itself is a field of historical inquiry, where recourse to experiment is impossible; therefore it must advance over a spidery network of hypotheses, few of which can be tested immediately. And in all such inquiry there is a human tendency to disparage someone else's legitimate hypothesis. To put it in the form of a Bertrand Russell conjugation, "*I* have scientific insight; *you* are carried away by your imagination; *he* indulges in irresponsible speculation."

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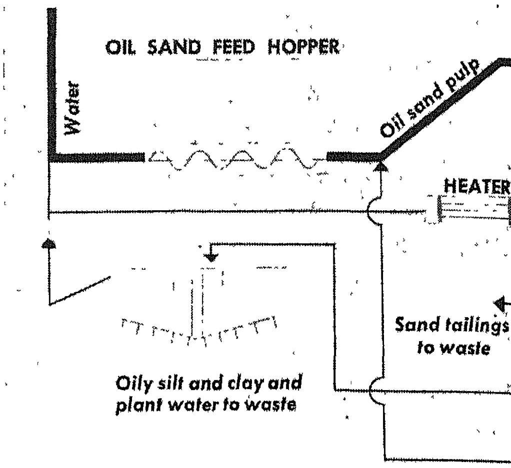
THE ATHABASKA TAR SANDS

They hold one of the world's great collections of oil. The studies of a practical process for extracting it are making encouraging progress

by Karl A. Clark



HOT WATER PROCESS now under test in Bitumount pilot plant

Along the Athabaska River in the Canadian Northwest, the cliffs that front the river are seamed for mile upon mile with thick deposits of black sands. These sands have been a taunt to North Americans for generations. They are the famous Athabaska "tar sands"—an immense bed of bituminous sand which holds one of the world's greatest accumulations of petroleum. The formation's visible outcrops alone cover an area of 1,000 square miles. In its total extent it is estimated to underlie 30,000 square miles of the region. Samples of its rich black sands contain from 12 to 17 per cent of oil by weight, and the deposits range up to 200 feet in thickness. Assuming conservatively that the sand formation as a whole averages 50 feet and bears 12 per cent of oil, a little arithmetic shows that its total oil content must be reckoned in tens of billions of barrels.

This oil cannot be won by the orthodox method of drilling wells and letting it flow. There is no gas pressure to drive the oil to wells, and in any case the oil is too heavy and viscous, at the temperatures prevailing in the formation, to be driven out by that method. Yet it lies ready to hand—a standing invitation to engineering ingenuity. The sand is so close to the surface that it can be excavated by power shovels in huge quantities. And the extraction of the oil from the sand presents no unsolvable problems.

The time has arrived when this great reservoir of oil must be regarded as of real, practical importance. Until recently it was considered an impressive but valueless natural phenomenon in a hopelessly remote area. There was plenty of accessible oil elsewhere. But times have been changing fast. The Athabaska country of Alberta is no longer remote or inaccessible. North American supplies of petroleum are not as ample as they were, and the demand for them keeps growing. The North American oil industry has reached out into South America and the Middle East for oil to meet its requirements. This situation would be satisfactory in a settled, peaceful world, but under the present uncertainty the danger of dependence on overseas sources in the event of war causes apprehension.

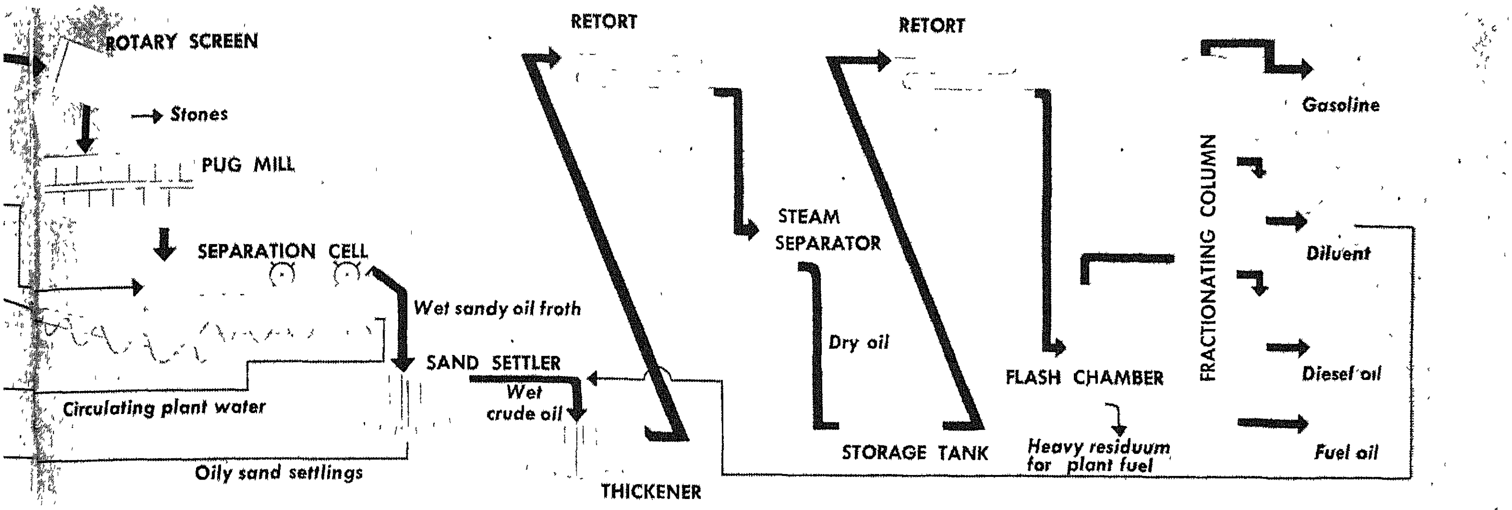
While much attention and money have been applied to studies of the production of oil from shale, natural gas and coal, the bituminous sands of Alberta are probably the most readily available secondary source of oil that the continent possesses During the war a hurried survey was made to determine whether enough was known about the extraction of oil from the sands to justify building a large-scale installation. It was found that while general methods were clear enough, practical details about plant design and operation were lacking. In view of the growing difficulty in meeting demands for oil, it is clearly advisable to learn how to build practical extraction plants and to find out what oil produced in them will cost. However this study may turn out—whether it shows that production of oil from the sands would be profitable now or should be deferred until there is greater need for it—it is important to determine the actual possibilities of the bituminous sands.

The Athabaska deposit is a huge alluvium of unconsolidated sand that was laid down on a delta of the geologic past. The strata are lens-shaped and irregular. Beds of silt and clay are scattered through the sand beds, and the sand beds themselves have a variable content of clay. Oil, finding its way into this deposit, soaked the sand but failed to penetrate the clay. Unlike deep oil formations that are buried under rock and high pressure, the deposit is relatively cold—about 36 degrees Fahrenheit. It is an oil reservoir that has been brought to the surface by erosion and now lies under a few feet to a few hundred feet of sandy and clayey overburden. Large sections of it have been laid bare by the Athabaska River, which cut a channel through the heart of the formation.

The oil in these sands is a very heavy, asphaltic crude with a high content (five per cent) of sulfur. Its A.P.I. (American Petroleum Institute) gravity rating is 10, compared with 35 to 40 for good grades of Mid-Continent crude. Ordinary fractional distillation of the oil yields a few per cent of gasoline and some light to heavy fuel oils; about 60 per cent of the crude is left as an asphalt residue But the crude is very susceptible to cracking. While it is not the kind of crude that a refinery prefers, it presents no problems that the refining industry does not know how to handle The value of the Athabaska oil, however, is not in its quality but in its vast quantity.

The story of these bituminous sands commenced when the first white fur traders found their way over the Indian canoe routes into the Athabaska and Mackenzie river system. The sands required no discovering There they were, flaunting their great extent and potential value in cutbanks 100 to 200 feet high for 60 miles along the Athabaska. In due time members of the Geological Survey of Canada traveled the canoe routes doing the groundwork of the geology of the region. They were greatly impressed by the bituminous sands, pondered about the origin of such a colossal accumulation of mineral oil, and speculated on how the huge resource might eventually be utilized.

In 1922 a railway to the Athabaska River was completed. Then came the discovery of an oil field near Fort Norman on the Mackenzie River, of gold on Lake Athabaska and later at Yellowknife on Great Slave Lake, and finally of uranium at the now famous Eldorado mine on Great Bear Lake. The airplane



is diagrammed in this flow chart. Tar sands enter through hoppers at left. After being heated to a hot pulp, they are put through a series of separations that remove sand and water and yield crude oil for refining.

made these mineral finds possible and has been used extensively in their development. During World War II facilities for transportation by water and by air into the North were expanded in connection with the Canol oil pipeline project, and these facilities have been further developed since the war to serve the rapidly developing mining camps centered on Yellowknife. Now the Athabaska and Mackenzie valleys are covered by an air transport system supplemented by railroad and by innumerable powerboats and barges plying the rivers and lakes.

Amid all this activity the bituminous-sand deposit remains virtually untouched. The seamed cliffs on the Athabaska carry a smirk on their faces, and no one who visits the Northland can miss its meaning. It says plainly: "You are doing big things with everything else in this North country, but I have still got you beat. When are you going to do something about it?"

The Geological Survey of Canada first took up the challenge in 1897-8. Hoping to find flowing oil at deeper levels, its geologists drilled into the formation at Pelican Rapids. At 740 feet they found rock-covered bituminous sands which contained gas under high pressure, but the oil was too heavy to flow In 1913 the engineer S. C. Ells, whose name and work are now inseparably associated with the Athabaska sands, was assigned to the study. He mapped the entire area and located all the bituminous-sand exposures. His maps are the basis for all present detailed work Ells also gave particular study to the utilization of bituminous sand as a paving material.

Soon after the railway to the Athabaska area was completed in 1922, the Research Council of Alberta began to investigate the problem of separating oil from the sands. In 1930 it built a small separation plant on the Clearwater River, a tributary of the Athabaska. The International Bitumen Company, which had a lease down the Athabaska at Bitumount, soon followed suit. A third pilot plant was built near McMurray, at the junction of the Athabaska and the Horse River, by Abasand Oils Limited, which was headed by the well-known petroleum geologist Max W. Ball, later Director of the Oil and Gas Division in the U S. Department of the Interior.

Beginning in 1942 these pioneering studies were supplemented by the Canadian Government, which began drilling operations to locate and prove large bodies of high-grade bituminous sand and took over the Abasand plant to study extraction processes. Unhappily the plant was destroyed by fire. The Government of Alberta thereupon entered the picture. At Bitumount, where the International Bitumen Company and a successor company had been unable to carry out their plans, it has built a separation plant which will be in operation this spring.

There are three general methods by which oil can be separated from bituminous sand. One is destructive distillation, which involves heating the sand in a retort to evaporate the oil The condensed oil is much lighter than the original oil in the sand In this process some of the possible products from the original oil—asphalt, for instance—are lost. Moreover, the bituminous sand must be heated to very high temperatures. Since 85 per cent of the material is sand, it is obvious that much wasteful heating is involved. To make the process a continuous one and reduce the waste of energy by providing a method of heat exchange would require a complicated plant.

A second method is to dissolve the oil out of the sand by means of an organic solvent and then to recover it from the solvent by distillation. This is a process that is used in the laboratory for analytical work. There are obvious difficulties in using it on a commercial scale. It saturates the sand with solvent instead of with oil, leaving the engineer almost where he was before—he must now find a practical method of recovering the solvent from the sand.

The third method is the so-called "hot water" process. The sand is agitated in hot water, whereupon the oil leaves the sand and floats on the surface of the water as a froth. This process has the advantage of simplicity and cheapness. The handling of hot water requires only simple equipment, and since water is cheap there is no need for great precautions against losing some of it. If the hot water is used more than once, heat losses are not serious

This is the method that was chosen as most practical by the Research Council of Alberta. It is the one used in all the plants thus far built, including the new plant of the Province of Alberta. The other two methods, however, continue to be studied in laboratories.

ATHABASKA bituminous sand is very amenable to treatment by the hot-water extraction method. Indeed, the problem is not to find a workable extraction process; it is to work out the engineering details involved in handling the materials. No plant so far set up has experienced any trouble in producing oil They have all had trouble, however, in keeping going mechanically.

It is necessary, in explaining the hot-water process, to make clear just what sort of stuff bituminous sand is. The mineral part of it consists of sand grains along with a variable amount of silty and clayey matter. The sand grains are composed almost entirely of quartz. The silt and clay is extremely fine material and is composed of silicates instead of just silica.

When excavated, the sand grains and the silt and clay are wet with water. The water, wetting the surfaces of the sand

grains, forms a film between oil and sand, hence the oil does not stick to the sand surface. The oil more or less fills the spaces between the sand grains.

If a little of the bituminous-sand aggregate is put into a beaker of hot water and broken up by agitation, most of the oil draws together into clots. The clots attach themselves to bubbles of air or water vapor which are always present and float to the surface. The accumulation of these clots forms a buoyant layer of froth. The clots, however, have enmeshed a good deal of sand in the process of formation, and when the froth is skimmed off it is found to be very sandy and, of course, to contain a great deal of water On a plant scale, the bituminous sand and water would be mixed and heated to form a hot, pulpy mass, which would then be poured into a tank of hot water. There the sand sinks and the oil floats, and each can be removed by suitable mechanical means. If the pulp is watery, however, the result is much the same as in the beaker experiment: the oil froth is very sandy.

The problem is to get a froth that is as free of sand as possible. This is done by forming a thick pulp with a minimum of water. In such a pulp the oil does not draw together in clots. It is dispersed in small masses, lying unattached among the sand grains. These oil masses vary in size, some of them being very tiny flecks. The silt and clay content of the bituminous sand is intimately associated with this dispersion of the oil. The more clayey the bituminous sand, the greater the proportion of fine oil flecks. All the oil flecks contain silt and clay, but the very small ones are the more heavily charged. If this type of pulp is abruptly flooded with hot water and is swept into a large tank of water, all the elements are dispersed and each constituent is fairly free to go its independent way. The larger oil masses fasten themselves to air bubbles and float to the surface. The sand grains sink. The silt and clay, along with the tiny oil masses, remain dispersed in the water. An oil froth is formed as usual. This froth, however, is fairly free from sand, provided another factor is controlled.

It is well known that oil-air bubbles have the ability to hold mineral particles and to float them. This phenomenon is the basis of the widely used flotation method of concentrating mineral ores. The phenomenon takes place in a hot-water separation plant just as readily as in a mineral-flotation cell. Air is necessary to form a buoyant oil froth, for the oil in the bituminous sands is actually heavier than water. But care must be taken that no more air is present than is needed to form the froth. Even this minimum of air will result in some sand being floated. The oil froth contains at least three per cent of mineral matter, of which about one and a half per cent is silt and clay. It also contains 35 to 45 per cent of water. Both of these contaminants must be eliminated.

The hot-water process recovers 80 to 85 per cent of the oil present in good grades of sand. The amount of recovery depends on the silt and clay content of the bituminous sand. Some of this very fine mineral matter is necessary for a satisfactory performance of the process. But too much of it causes loss of yield because of increased dispersion of oil in the plant water.

A description of the Provincial Government plant at Bitumount, which is set up to produce 350 barrels of oil a day, will show how the process is translated into full-scale plant operation. At Bitumount 60 feet of good grade bituminous sand lies exposed in the east bank of the Athabaska River under a few feet of overburden. The quarry site was stripped of eight feet of sandy soil and weathered material by bulldozers, power shovels and dump trucks. The bituminous sand for the plant feed is dug directly from the quarry by power shovel and is carried by truck to a bin at the head of the separation plant.

A SIMPLIFIED picture of the stages in separation of the oil from the sand is shown in the diagram on pages 52 and 53. After being dumped into the bin, the sand is discharged through hoppers at the bottom into screw conveyors that carry it from the hopper into the plant. These conveyors are steam-jacketed. Hot water is admitted into them in controlled amounts. Thus in addition to conveying the sand, they mix it with water and heat the pulp. The pulp is passed through a rotary screen to catch stones and then into a pugmill where the mixing and heating of the pulp is completed. The pulp then drops from the pugmill into a circulating stream of hot water that washes it into a "separation cell."

Up to this point the oil has been dispersed in small masses among the sand grains in the pulp. The stream of hot water that it encounters has previously been stirred up to considerable turbulence. On meeting the stream of water, the pulp is completely dispersed by its turbulent flow. The agitated water also provides the air bubbles that float the oil. It rises to the top of the cell in a froth. The sand sinks.

The circulation of the hot water is a key feature of the plant. The stream of water that enters the separation cell overflows from it. The outflowing stream carries silt and clay and some oil in the form of very small flecks heavily charged with silt and clay. The stream is then pumped to a cylindrical container where the solid material settles at the bottom and is discharged to waste with the help of a mechanical rake. The water, cleared of this sediment, overflows at the top of the container and is returned to the separation cell. On its way it passes through a heater which brings its temperature back to about 185 degrees F. It enters the beginning of the cycle again through a small box in which the turbulence of flow is created. Aeration can be controlled by reducing the circulating water stream and thereby the turbulence. Automatic equipment regulates water levels, pump actions, heating and introduction of water.

The separation cell is a simple vessel. The sand that sinks in it is pushed out at the bottom by a horizontal screw conveyer. The oil froth that collects on the water surface is skimmed off by a simple paddle device. It then goes to a tank where the froth collapses to a flat layer of oil and the sand particles still left in it sink. The oil, now freed of abrasive sand grains, overflows and is carried off for its final treatment.

The separated oil, as already noted, contains from 35 to 45 per cent of water and about one and a half per cent of silt and clay. The water, particularly, must be removed or at least reduced to a low, constant amount before the oil can be sent to the refinery. This result is accomplished by a method introduced by Abasand Oils Limited. It consists in mixing the wet oil with a refinery distillate of about the volatility of kerosene. The addition of this diluent amounts to at least 70 per cent of the volume of actual oil present in the wet oil. The resulting oil mixture has much greater fluidity than the crude oil, and its density is less than that of water. Consequently water will sink in it. The water of the wet oil is present in all degrees of dispersion, from slugs to the tiniest of droplets. The hot mixture of wet oil and diluent goes into a tank where much of the water settles, either as clear water or as a gelatinous emulsion containing some clayey matter and oil. The water is discharged from the tank, and rakes at the bottom move the emulsion with it.

The oil which overflows from the top of this tank still contains some water. It is dried by driving the water out by heat. The dried oil then goes to a small refinery in the plant. There the diluent is recovered and the crude oil extracted from the sands is fractionated into a little gasoline, diluent for use in the plant, Diesel oil and the residuum. Since the purpose of the project is simply to establish a cost for the produced oil, all that is required of this refinery is to reclaim diluent and to produce fuel for the power plant; the rest of the crude oil constitutes the product. If the Bitumount plant operations are successful, it is likely that the refinery will be made more complete. What seems called for is a coking unit which would break down the asphalt residuum of the crude oil into coke and cracked distillate. The coke would serve as fuel

in the power plant and the distillate would be fractionated into the refinery products of gasoline, Diesel oils and fuel oil. Destructive-distillation tests on the crude oil show that it breaks down into about 20 per cent coke, 5 per cent gas and 75 per cent distillate. This proportion of coke and gas is about right for the fuel supply of a complete extraction plant and refinery. The distillate has an A.P.I. gravity of approximately 25. It is quite fluid.

THE opening stage of large-scale development of the bituminous sands will be the construction of separation plants in a few favorable areas. Three such areas are known now, each approximately a square mile in extent. They contain from 100 to 200 million barrels of oil each. It is almost certain that exploratory drilling will reveal a number of other good sites. One may visualize the area, in future years, dotted with huge open-cut pits with separation plants nearby—instead of the familiar oil-field scene of derricks. These installations would excavate the sand, extract the oil in a plant and crack the oil to coke and crude distillate, burning the coke for fuel and piping the distillate out of the field as crude for the market.

To get at the billions of barrels of oil in sands that lie too deep for excavation is another technical problem, the answer to which at present is far from obvious. Much of the sand is buried under an overburden of 100 feet or more, and the good grades of sand often lie near the bottom of the formation. Some attention has been given to the problem. Several experimenters have tried to drive the oil out of the beds with heaters of various sorts in boreholes. If for no other reason, these attempts failed because of the very low heat conductivity of bituminous sand. The Research Council of Alberta gave some study to the possibility of flooding the beds with water. However, a determination of the viscosities, permeabilities and temperatures involved showed that this method could not be used unless a way could be devised of heating the bituminous sand beds from 36 degrees F. to about 150 degrees. No way to do this is apparent. The problem remains difficult, but it will be solved.

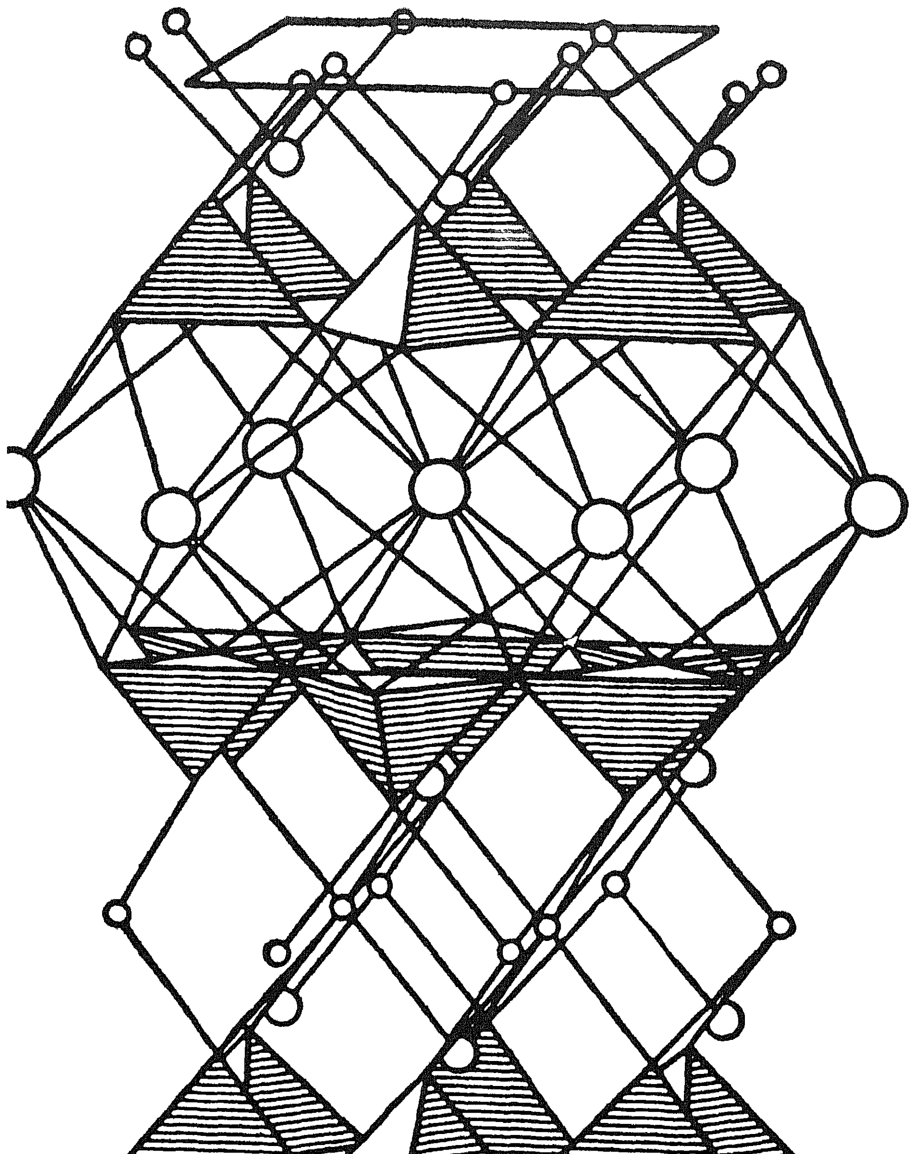
Meanwhile, operations at the Bitumount plant should settle the question of the practicability of oil production from the accessible sands. When the technical questions are resolved it will be up to the policy makers inside and outside of industry to decide whether the challenge of the bituminous sands is to be allowed to stand or whether something is really to be done about it.

Karl A. Clark is Research Engineer of the Research Council of Alberta.

BITUMINOUS SANDS here seam the face of tall cliffs along the Athabaska River. Exposed deposits cover an area of 1,000 square miles in the region.

MINING OF THE OIL requires no wells or drilling. Oil-bearing sands are simply scooped up by steam shovels and carted to the extraction plant.

EXTRACTION PLANT was first built by Research Council of Alberta on Clearwater River. New plant on Athabaska begins operations next month.



MOLECULAR STRUCTURE of muscovite mica is an illustration in *The Structure of Matter*. Pyramidal structures are an oxide of silicon (SiO_4). Smallest circles represent atoms of aluminum (Al). Larger circles represent the hydroxyl radical (OH). Largest circles represent potassium (K).

by E. U. Condon

THE STRUCTURE OF MATTER, by Francis Owen Rice and Edward Teller. John Wiley and Sons ($5.00)

If one were to say "atom" in a word-association test, the vast majority of persons would doubtless answer "bomb." Obviously the importance of a knowledge of atomic theory is far greater than this association of words would imply. This book does not even mention the bomb.

The fact is that since all matter is made of atoms, and all of science is concerned with the behavior of matter and its interaction with electromagnetic radiations, there can be no knowledge of science which does not involve a comprehension of modern atomic theory.

The Structure of Matter is an admirable attempt to give the serious student of physical science an introduction to modern atomic theory. The mathematics in it is confined to simple algebraic formulas. Therefore it is completely non-mathematical from the standpoint of the mathematical physicist. On the other hand, the book is clearly not "popular." A popular book must contain not one line of algebra in spite of the fact that millions of Americans, including book publishers, have studied algebra.

The authors have taken as their task the presentation of the concepts of atomic theory and their application to a wide range of physical and chemical phenomena. In order to get on with the job, they do not give complete deductive treatments. They have omitted any account of the historical growth of the underlying ideas. They have also dispensed with any discussion of philosophical consequences or basic concepts of measurement associated with the celebrated uncertainty principle of quantum mechanics.

Instead they plunge at once into a descriptive account of the concepts of quantum mechanics and of the nuclear model of the atom. In the very first sentence of the book they set out with a high degree of confidence in the power and correctness of present-day theory. They say: "At present, atomic physical theory in principle enables us to calculate all of the chemical and most of the physical properties of matter and thus

BOOKS

An ambitious introduction to all of modern atomic theory and its applications in physics and chemistry

makes the science of experimental chemistry superfluous."

That is certainly promising a good deal, and would provide a show well worth the price of admission. However, the next sentence goes on to say that the necessary calculations are so laborious that it is much easier in most cases to do the experimental work rather than attempt to make the theoretical calculations. Thus it turns out that the experimentalists are not yet unemployed.

Of course, it is an act of faith to suppose that the calculations which have not been made would, if they really were made, agree with experiment in every detail. Since they have not been made, nobody can be sure that they would agree with experiment in all the untried cases. Nevertheless it is true that the power of the quantum-mechanical method applied to the electron-nuclear model of the atom has been so astonishingly fruitful in correlating observational information about nuclei, atoms, molecules and solids that one cannot help feeling a high degree of confidence in the unqualified introductory sentence of this book. Many people need just some such assurance before they will make the effort to master what follows. For others the study is made more piquant by the possibility of discovering some new phenomenon that did not fit the theory and that would require some fundamental revision of it.

Teller and Rice deal with an astonishing range of subject matter in a way that should be genuinely helpful to a person seeking a descriptive introduction to the wide range of successes of the theory. By departing completely from the historical order of development the authors are free to use whatever presentation is best suited to clarity.

The book has one very serious defect, however, which seems to be connected with this avoidance of historical allusion. The defect is that almost no references are given either to original research papers or to other expository material. Thus the student is left almost completely without guidance as to where to find more detail on any one of the topics discussed.

To review *The Structure of Matter,* it is necessary to explain briefly what the book has left out—an account of the main periods that produced the developments with which it deals. We often hear of the flowering of science that occurred in the 18th century Today we are dealing with a rate of change much faster than anything that occurred in that great century.

We have come a long way in our knowledge of atomic structure in the last 50 years, and particularly so in the last 25 years. Fifty years ago physicists were just beginning to be acquainted with the electron as a tiny corpuscle of negative electricity and as a probable constituent of atoms. The game of thinking seriously about atomic structure began. Radioactivity and X-rays had just been discovered, as had the photoelectric effect and the emission of electrons from hot bodies

At the turn of the century a disturbing element was rudely introduced by Max Planck's quantum theory of radiation. Up to that time the successes of the wave theory of light in accounting for phenomena of interference and diffraction had been so great that it was regarded as fully established. Planck's discovery showed that one had to regard the emission or absorption of light not as being a continuous process, as had been thought, but as involving in a single process a single quantum of energy, the amount being proportional to the frequency v and conventionally written as hv. The h was the new constant discovered by Planck in this connection

The implications of Planck's revolutionary idea were not apparent at once. They lay deeply immersed in a complicated mathematical theory that few could critically understand. For some time many thought there was a less radical approach to radiation theory than the one Planck felt forced to adopt.

In 1905, however, Albert Einstein showed how the quantum hypothesis of Planck led to simple and straightforward interpretations of some data of the photoelectric effect. Einstein also showed its applicability to the study of the heat capacity of solids at very low temperatures. From then on the place of the Planck constant, h, in the future of physics was assured

By 1912, Ernest Rutherford had performed his crucial experiments on the scattering of high-speed alpha particles by the atoms in thin metal foils. He was able to show that the distribution-in-angle of the scattering of such alpha particles required the assumption that the heavy part of an atom was concentrated in a small nucleus, not more than 10^{-12} (1/1,000,000,000,000) centimeter in diameter. The outer part of the atom, where the electrons are, occupies a space about 10^{-8} (1/100,000,000) centimeter in diameter. Thus in 1912 the nuclear model of the atom was born.

From that time forward we have understood that an atom has a central, positively-charged heavy nucleus that is surrounded by a number of electrons The atoms are electrically neutral, and the atoms of chemically-distinct elements differ both as to the amount of positive charge on the nucleus and as to the number of electrons surrounding it

From 1912 on the pace quickens at a rapidly-accelerating rate. The great problem, of course, is that of the dynamics of the process by which the electrons move around the nucleus. Also of large significance was the relationship that this bears to the quantum process by which changes in the atom are connected with the emission and absorption of radiation. The first decisive steps to solve this problem were taken in 1913 and 1914 by Niels Bohr.

Bohr introduced the concept that atoms, and chemical molecules, exist only in definite states having fixed possible amounts of energy. He supposed that certain values of the energy correspond to possible states of atomic systems; that a system simply could not exist in a condition where it possessed intermediate amounts of energy. Emission or absorption of radiation he connected with the process of abrupt discontinuous transition from one "permissible" state to another.

Physics was quite fully occupied for a decade in working out the many implications of Bohr's ideas. The gate was opened to a detailed interpretation of the spectra of atoms and molecules. This in turn not only gave support to the theoretical principles but also gave a wealth of new quantitative information about the atoms and molecules. X-ray emission and absorption spectra were discovered and analyzed and explained by the new theory. The behavior of atoms and molecules when subjected to electron bombardment also became understandable and contributed a wealth of detail to the unfolding picture.

And yet from the very beginning Bohr was aware of the inadequacy and incompleteness of his theory. He worked constantly to focus the attention of theoretical physicists on these shortcomings,

to the end that progress might take place on a more solid foundation than that which he had been able to provide. Besides the difficulties of a fundamental kind which Bohr stressed, his early quantized-orbit model of the nuclear atom proved quite incapable of giving an account of the nature of valence forces holding atoms together in compounds—the basis of all chemistry.

This deeper concern with improved foundations of the theory bore fruit just a quarter-century ago and soon thereafter, in the theoretical and experimental discovery of the wave nature of the electron by Louis de Broglie in France, by Erwin Schrodinger in Zurich, by C. J. Davisson and L. H Germer in New York. Soon the mathematical theory of atomic phenomena unfolded in a period of dazzling brilliance at the hands of Max Born in Gottingen, Werner Heisenberg in Leipzig, P. A. M. Dirac in Cambridge, and many others.

By 1927 a thoroughgoing revolution in the basic concepts had occurred. For a year or two thereafter hardly an issue of the important physical journals appeared that did not contain some paper that pointed the way to a whole new kind of phenomenon like the barrier-leakage interpretation of radioactive decay, or the Fermi-Dirac statistics for electronic properties of metals, or the Heitler-London theory of the homopolar valence bond, or the interpretation of alternating intensities in band spectra due to spin and statistics of nuclei, and so on. In the years 1927 to 1930 the rate at which new ideas of the utmost importance were being discovered in theoretical physics was staggering, and many of the best physicists were staggered by their attempts to keep up with the mainstream.

With the 1930s came another decade of great progress. Besides a rather complete working out of the most complicated atomic and molecular spectra, there came also an important application of quantum-mechanical ideas in two quite different outlying areas. In one direction real progress was made in the basic interpretation of the forces holding atoms and molecules together in solids, and therewith a fuller understanding of the mechanical, thermal and electrical properties of solid substances. In another direction the whole science of nuclear physics was born, with the discovery of the neutron and the development of high-voltage equipment permitting the ready transmutation of elements by bombardment with particles of high energy.

All this splendid intellectual development was slowed almost to a standstill in the present decade when the physicists were called upon to quit their peaceful occupations and devote themselves to the development of new tools for the war. Since 1945, however, the quest has been taken up again. A whole host of new basic discoveries is coming from the laboratories. Physics is still an exciting game full of rich rewards, but it is one in which the range of detailed achievements has become so great that it is beginning seriously to be fragmented into small specialized areas. It is no longer possible for any one physicist or chemist to keep abreast of all the research fields which are dominated by the concepts and ideas of quantum mechanics.

What a story! A complete account, of course, includes many false starts and excursions up blind alleys. But if one judiciously leaves out some of the waste motion, there is much to be said for a presentation that follows the historical order purely as a way of organizing the study apart from the human interest attaching to the actual history of the development.

Rice and Teller have omitted all this. This reviewer regrets their decision. They have nevertheless produced a book that should prove very valuable to many beginning professionals who wish to get started in this vast field of modern theoretical physics.

E. U. Condon is director of the National Bureau of Standards.

HUMOR AND HUMANISM IN CHEMISTRY, by John Read. G. Bell and Sons Limited, London. A DIRECT ENTRY TO ORGANIC CHEMISTRY, by John Read. Methuen and Company Limited, London. Two extremely able books from the prolific pen of a scientist noted equally for his original researches and for his delightful contributions to the cultural history of chemistry. *Humor and Humanism*, a successor to Read's well-known *Prelude to Chemistry*, touches upon a variety of entertaining curiosities and out-of-the-way matters such as "the flying alchemist"; the scientific pursuits of James IV of Scotland, who paid people for practicing dentistry upon them (Lord High Treasurer's entry, February 9, 1511: Payment of 14s. to "ane fallow, because the King pullit furtht his tootht"); early chemical textbooks, chemistry in the Australian bush; and the effects of laughing gas and other "factitious airs" on human subjects. There is a chapter on the habits of some of the modern greats in chemistry, in part based upon Read's personal experiences during his student years in Zurich, another chapter on "chymical artists," and a large number of uncommonly interesting cuts and plates. *A Direct Entry to Organic Chemistry* appears in the attractive, inexpensive and highly satisfactory Home Study Book Series. (Why U. S. publishers offer no adequate counterpart of ventures of this kind, especially in the sciences, is incomprehensible.) The analogies, historical allusions, anecdotes and clear style combine to make this popular introduction to a difficult subject, whose clumsy symbol-

ism makes it particularly repellent to the plain reader, the best English work of its kind that has yet appeared.

THE CITY OF REASON, by Samuel H. Beer. Harvard University Press ($4.00). Professor Beer argues that although there is undoubtedly a relativity of truth and of morals, certain fixed duties, ideals and principles constitute an ethic of civilization sufficient to explain "the larger notions which lie behind our moral feelings," to counteract the frustrations of irrationalism, to make men the ultimate masters of chance and to effect what would universally be described as "progress." The principles are those of community, reconciliation, and reason, the ideal is "a community in which the happiness of each integrally involves the happiness of all." Dr. Beer's assertion of a creative universe of which the human mind is "a peculiarly creative part" is derived from John Dewey and to an even greater extent from the philosophy of the late Alfred North Whitehead. An intelligent, gentle, sincere and often eloquent book which may offer solace to some, but can hardly persuade those who are not at least half-persuaded at the start.

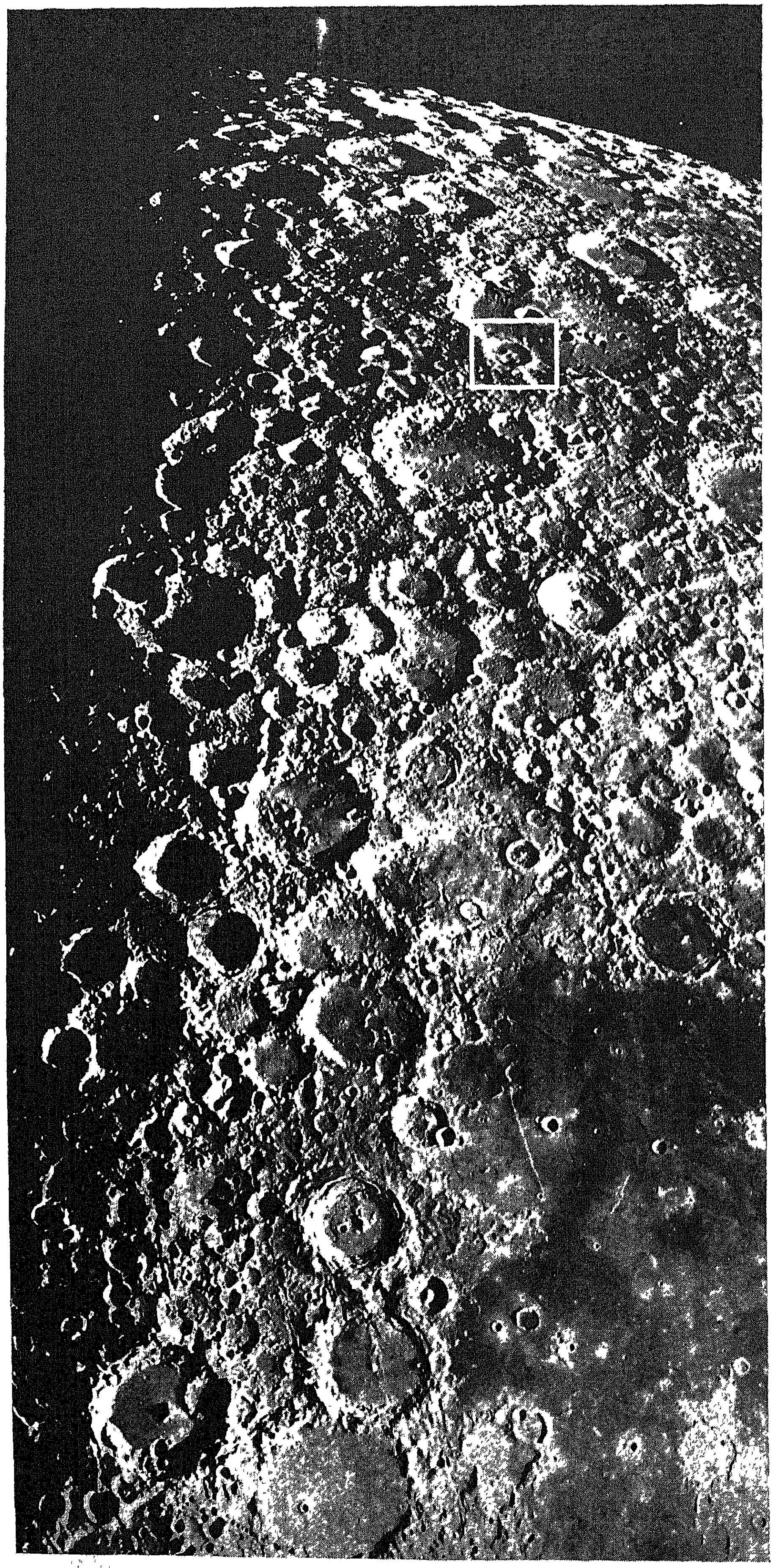
THE BOOK OF THE SHIP, by A. C. Hardy. The Macmillan Company ($8.00). An illustrated survey of the world's non-fighting ships, the shipping trade and the shipbuilding industry. There are chapters on ship and marine-engine construction, the purposes of various ship designs; harbors, docks, and the repair of ships, dredgers and hoppers, lighthouses and sea marks. The tables, silhouettes, photographs and glossary enhance the value of an authoritative manual written in a clear, nontechnical style.

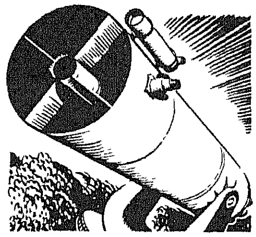
READINGS IN PHILOSOPHICAL ANALYSIS. Selected and edited by Herbert Feigl and Wilfrid Sellers. Appleton-Century-Crofts, Inc. ($5.00). A volume of carefully selected articles giving a representative view of modern philosophical schools of thought. While there is no dearth of philosophical readers (*i.e.*, books), few anthologies include, as does this one, basic essays by outstanding authorities on the nature of logic and mathematics, language, meaning and truth, induction and probability, theoretical ethics and scientific method. With its useful bibliography, this collection should not only enjoy welcome in universities but can be recommended to anyone interested in the fascinations of modern philosophy.

ALBERT EINSTEIN, by Elma Ehrlich Levinger. Julian Messner, Inc. ($2.75). ALBERT EINSTEIN: A BIOGRAPHY FOR YOUNG PEOPLE, by Catherine Owens Peare. Henry Holt and Company ($2.50). Brief accounts of the great physicist's life with laudable emphasis on his humanity and pacifism. Unfortunately, in their eagerness to portray him as a genius and as a saintly man with lovable eccentricities, both authors fail to make Einstein out as a credible, three-dimensional mortal. No attempt is made to explain his scientific work either in quantum theory or relativity, which can be and has been done even for young people, though Mrs Levinger goes a little further in this respect than Miss Peare, also, there is a striking similarity between the ancedotes and fables appearing in both biographies. Mrs Levinger is given to confecting imaginary (and implausible) conversations. Any child who wants to read a biography of Einstein deserves better.

THE SECOND WORLD WAR, by Major General J. F. C. Fuller. Duell, Sloan and Pearce ($5.00). A brief history of ground and air operations of the last war by one of the ablest and most prejudiced of military analysts. So long as General Fuller, Britain's first tank commander, writes about things he understands, he is reliable as well as readable; even his bias against strategic air power does not vitiate his acute criticism of its misuse. Unfortunately he insists on mixing straightforward military criticism with much nonsense about social and political matters: warfare, he laments, has now fallen into the hands of the "cadocracy," which is what makes it so unpleasant.

NEW COMPASS OF THE WORLD. Edited by Hans Weigert, Vilhjalmur Stefansson and Richard Edes Harrison The Macmillan Company ($5.50). A balanced and informative symposium on various topics of political geography (geopolitics), a subject usually discussed in grandiose and inflated terms. The editors have gathered contributions on the Arctic and Antarctic, the U.S.S.R., U. S. and British policy with respect to strategic bases, the political and economic problems of Asia, population trends and world biological resources. Several of the essays, including those by Stefansson, Weigert, Owen Lattimore, and G. C. L. Bertram, are models of disinterested analysis of controversial matters, in contrast with what passes for the same in the daily press and the whooping best sellers. The author of *The Road to Survival,* for instance, would lose his power over your maiden aunt once she read Bertram's cool appraisal of how soon we can all expect to expire from starvation. This book is a successor to *Compass of the World,* in which the same editors warned of "the dangerous beginnings of an American geopolitics . . . against the false values of a new Manifest Destiny based on geographical half truths." "We feel," they now write, "the same way today, four years after." They are, it may be supposed, not alone in their apprehensions. J. R. N.





Conducted by Albert G. Ingalls

LAST month this department carried an account of the life of Russell W. Porter, the patron saint of amateur astronomers who died on February 22 At the end of the account it was mentioned that a crater on the moon had been made a memorial for Porter. This was the happy outcome of a suggestion first made 10 years ago by David P. Barcroft, a well-known planetary observer of Madera, Calif Encouraged by Walter H. Haas, widely known for his lunar observations, and by this department, Barcroft wrote to H. P. Wilkins, F.R.A S., Director of the Lunar Section of the British Astronomical Association, who at once replied as follows.

"I fully agree that Porter is entitled to a place on the moon and am very glad indeed that it lies within my power to further this. One of the finest of all the lunar formations is Clavius. On the walls of Clavius we find two prominent craters, one on the south wall and the other on the north. They used to be known as Clavius A and B. The one on the south is now called Rutherford after the famous American lunar photographer but, until the present time, the crater on the north wall is still unnamed It is about 25 miles in diameter I therefore propose to name the crater Clavius B, Russell W. Porter.

"To this end I have already inserted it on my copy of the 300-inch map and on the tracings from which prints are taken, and this name will appear on all future copies of the map. I do not think I could have selected a better object.

"I will also see that appropriate action is taken by the various learned societies, so far as lies in my power. The chief step has been taken. the name is now on the map." No doubt this action will be sanctified by the Commission de la Lune of

RUSSELL W. PORTER is the name of the crater within the white rectangle on this Mount Wilson photograph of the moon. Above it lies the larger object Clavius. Formerly Porter was known as Clavius B (*see drawing at the right*).

CLAVIUS is a mountain-walled plain pocked with smaller craters. Clavius B, or Porter, contains twin peaks.

THE AMATEUR ASTRONOMER

the International Astronomical Union.

The conviction that this kind of memorial would have been appreciated by Porter is based on some comments he penciled on the back of a letter in 1944. His attention had been called to the writer's attempts to rename Breezy Hill, on which his home "Stellafane" rests, "Mount Porter." His comments were.

"Well, I cleaned up 3,000 square miles of unknown blanks in Franz Josef Land and 3,000 more in Alaska but my name is not on one island, point, bay or lake. Oh yes, there is a lake in Baffin Land that my party discovered and put my name on, so I suppose I ought to be satisfied Anyway it was a sizable lake, six miles long and a lot bigger than Breezy Hill (which I did not discover)."

Where is the crater now named Porter? It is indicated by the white rectangle on the Mount Wilson photograph of the moon which appears on the opposite page. Above it lies the great mountain-walled plain Clavius.

Amateurs will now eagerly aim their telescopes at the moon, at Clavius, and at Porter, and will study their minute features with special interest. No equally detailed description of these exists other than that which appeared in the classic work *The Moon*, by Walter Goodacre, today out of print, obtainable even at second hand with great difficulty and at a cost of about $25 (originally $7.50).

In his book Goodacre, who until his death in 1938 was the Director of the Lunar Section of the British Astronomical Association, says this about the crater:

"*Clavius* —A noble object at all times, being a vast walled depression 140 miles in diameter. The inner terraced slopes rise upward to the crest, which is 12,000 feet above the floor The aspect which this object presents when seen under a low sun is one of remarkable grandeur and absorbing interest The crest of the wall is nowhere circular but is composed of a number of linear and irregularly curved sections presenting strongly marked polygonal features. The height of the crest generally above the surrounding country is insignificant and in many places it does not exist, the inner slopes dropping sheer from the surrounding surface. At several places along the inner slopes are evidences of landslips on a large scale.

"A is about 28 miles in diameter and, with B on the north wall are evidently much older formations than the regular circular craters found on the floor. A contains a fine peak; its floor is very rough. From the north wall of A radiate ridges which Elger compares to the ribbed flanks of some of the Java volcanoes. Some of these reach nearly to B. Professor W. H. Pickering has also noticed similar ridges on the outer slopes of some of the Hawaiian volcanoes

"B is similar in type to A and probably contemporary in point of age, it contains a fine double-peaked mountain and a crater under the north-east slope. Between the central mountain and the south wall are three minute craters in a row east to west, quite good test objects

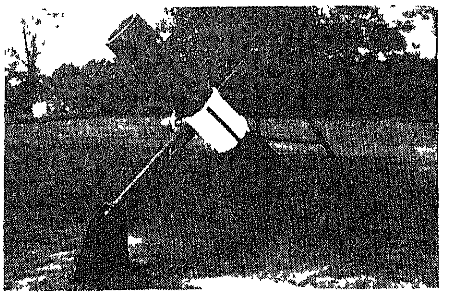
"The floor of Clavius is very smooth generally, but sprinkled over with many craters, craterlets and crater pits. Among these there is between A and B the fine clear-cut crater D, with walls rising 3,000 feet above its interior, having a small central mountain. Outside its wall on the east is a small isolated peak with a minute crater a little to the south

"In addition to D there are four other large craters of the same type running in a curve convex to the north, decreasing in size as they go. The mountains in A and B have very smooth, gently rising sides very much resembling large sand dunes

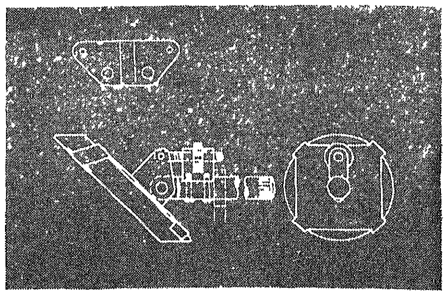
"Between D and the west wall are seven or eight craterlets arranged in an elliptical curve. I find these are good test objects for a 10-inch object glass, they are faintly shown on the Mount Wilson photograph."

The walled plain Clavius was named in 1651 by Joannes Baptista Riccioli for Christopher Klau, a German Jesuit mathematical teacher, according to *Who's Who in the Moon*, published in 1938 by the Historical Section of the British Astronomical Association. After examining this 130-page catalogue, R S. Richardson of the Mount Wilson Observatory listed in Leaflet 193 of the Astronomical Society of the Pacific (March, 1945) the following Americans whose names have thus far been given to features of the moon Bruce, Burnham, Mitchell, Hall, Newcomb, Ritchey, Rutherford, Lick, Yerkes. To this short list the name of Porter may now be added.

THE reflecting telescope shown in the photograph at the top of the next page was designed and built by Captain William C. Bryson, U. S. N., of the U. S. Naval Proving Ground, Dahlgren, Va., assisted by Donald L. Winchell and Walter N. Larsh. Captain Bryson states that its mounting was patterned after the prototype sketch of the English yoke mounting shown in *Amateur Telescope Making*, page 139, and says "I have found this to be a very satisfactory type of mounting." Oddly, however, this mounting, so easy and inexpensive to build, so portable, so attractive, so rock-rigid if well built, has not often been made by amateurs. It is the same type as the



Captain Bryson's telescope



McCartney's secondary support

mounting of the 72-inch reflector at the Dominion Astrophysical Observatory, Victoria, B. C.

The buried south pier of the Bryson telescope is made of welded steel Pivoted on a ball bearing is the thick polar axis, a length of 4½-inch steel pipe. At its top this pipe is similarly carried on a ball bearing at the apex of a bipod or A-frame of welded pipe.

The lower legs of the bipod slide within the upper parts and may be adjusted to the desired height and held by means of hand screws. "Like most Navy men I never know what the latitude of my next duty station will be," Captain Bryson states. At whatever latitude, the bipod legs need only be adjusted until the polar axis is parallel to the earth's axis.

"The tube," he continues, "is made of wood and its cross section is a regular polygon of nine sides, a convenient multiple of three to accommodate the three-legged spider that holds the diagonal prism. For added strength every third stave is of oak rather than pine and there are six internal reinforcing rings.

"The tube is clamped removably to a saddle attached to one end of the declination axis. When it becomes necessary to rotate the tube to obtain more convenient access to the eyepiece as the telescope is swung in following the stars, I have to swing the tube back across the polar axis, unclamp the tube, and bodily roll it over. I'm not very happy about this feature. I want external concentric tube rings so I can rotate the tube without wrestling My advice to other amateurs would be to get a cylindrical tube at the outset.

"The white 'corset' around the tube is a canvas chafing gear to protect its corners. I store the tube in our dining room (not unopposed) and when I added this corset my wife irreverently draped female garments on it.

"The declination setting circle and vernier is made of brass and pivoted on the declination axis and, by means of the knurled knob visible between vernier and polar axis, it can be cast loose and readjusted to read correctly when the telescope is on a star of known declination, a principle explained in *Amateur Telescope Making*. The declination circle is divided in degrees, 10 graduations on the vernier spanning 9 on the circle, and thus the vernier can be used to set the telescope in standard one-tenth degree increments of declination."

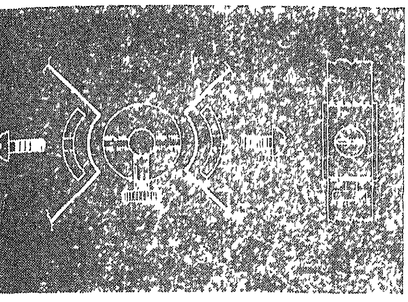
DETAILS of a support for the secondary mirror of a Newtonian reflecting telescope, as designed by E. B. McCartney of Minneapolis, Minn., are shown in the first two of his three drawings reproduced above. "This support," he states, "has been used in three telescopes and is the easiest to make and adjust of any I've seen. It is shown with a homemade flat but can be used with a prism. Tilting the flat does not throw it far off laterally, as in some designs. It should be made 'tight' and if this is done no locks will be needed."

The first drawing is a side and end elevation. The second drawing is an exploded plan and elevation of the spider hub into which the main rod of the secondary support is adjustably fixed by means of the thumbscrew shown.

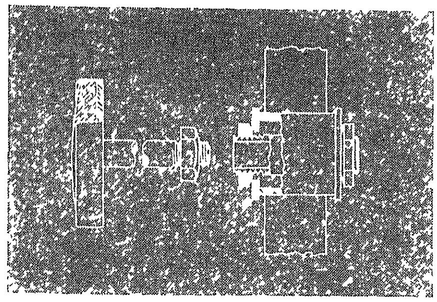
The third drawing represents an adjustable support for the secondary of a compound telescope. The spherical nut and, at the opposite end of its stud, the spherical washer, explain the three-dimensional adjustment afforded by this support. McCartney is the designer and builder of the "Hempstead Hydrant" mounting shown in *Amateur Telescope Making—Advanced* on page 330.

INCLUSION in *Amateur Telescope Making—Advanced* of the chapter entitled "Dealing with Spider Diffraction" has led to a considerable development of forms of curved supports for secondary mirrors because these abolish the spikes that seem to project from bright stars. Franklin B. Wright of Berkeley, Calif., in a recent letter takes a similar point of view. "I think," he says, "the idea is much overrated. There are occasions when it would be handy to put something over the straight ribs to spread the diffraction streak from a near-by bright star. But it is usually possible to rotate the telescope tube to move the diffraction streak out of the way so that it will not obscure an object.

"The objection to the curved ribs," he continues, "is that the total light spread outside of the central image of a point source is bound to be greater than for thin, straight ribs because the curved ribs must be longer and thicker in order to be sufficiently rigid. This difference



Exploded drawing of support



The adjustable support

would not be important except when the moon, large and bright planets, or the sun were being viewed. In such an event every bright point on the object would appear to be surrounded by diffraction either in the form of straight streaks or an even spread all around the point, depending on the form of the supporting ribs whether straight or curved, the diffraction always being at right angles to the part of the rib which causes it and extending both ways from the image of the bright point.

"These diffraction images, no matter what form they have, would be duplicated all over and around a bright extended object such, for example, as the moon. This is because of the infinite number of bright points on the surface of the moon, each one acting as a source and producing one of the diffraction patterns at the image plane.

"Therefore, no matter what the diffraction pattern might be for an individual object, the combined effect of these overlapping patterns would be one big blur of scattered light overlying and extending beyond the image of the moon. Since the total amount of diffracted light is greater with curved than with straight ribs, it follows that the scattered light would be brighter and would interfere more seriously with the clearness of faint markings when curved ribs are employed on extended objects such as the moon.

"The only thing that could afford a worthwhile improvement on thin, straight ribs under tension would be to support the diagonal on an optically figured, nearly flat glass plate or correcting lens near the focus, or to take the diagonal entirely outside the cylinder of light as in the Herschel telescope or some other of similar type."

The curved secondary support gets rid of the spikes on stars but does not get rid of the diffraction. This fact was pointed out in *Amateur Telescope Making—Advanced* on page 620.

PHOTOGRAPHS of terrestrial objects, the sun and moon, says Lyle T. Johnson of La Plata, Md., may easily be taken with any camera and any telescope. Johnson's method is merely to open the camera diaphragm, focus the camera at infinity, hold it almost in contact with the telescope eyepiece, and snap the camera shutter. "I have been doing this for years," he writes, "but found sometimes that the photographs were out of focus, especially when using a short-focus mirror in the telescope. I then stumbled on the idea of looking through the telescope with a small telescope such as one side of a binocular, previously focused independently on a distant object, and adjusting the eyepiece of the large telescope."

Explaining the principle involved, Johnson states. "The large telescope must in some way be brought to such a focus that the light emerges from its eyepiece in parallel rays, that is, at infinity. Unfortunately the eye, because of its power of accommodation and defects if any, does not afford close estimate of the correct infinity focus of the telescope. But when a telescope has been focused on a distant object the light rays entering it from a point source must be parallel or very nearly so to give a sharp image. Now if this small telescope, previously focused, is placed between the eye and the eyepiece of the large telescope, the indefinite accommodation factor of the eye is eliminated"

When taking the picture the iris diaphragm of the camera should be opened wide so that no part of the Ramsden disk of the telescope will be cut off. Theoretically the Ramsden disk should be in the center of the camera lens, but this is not important.

Of course, if the camera has a groundglass focusing screen the use of the auxiliary telescope as described above may be dispensed with and focusing done directly, since the accommodation of the eye will no longer be a factor.

IF IN a knife-edge mirror tester the knife-edge is on the left and the pinhole or slit is on the right, and the right eye is used at the slit, then the screw that moves the knife-edge is likely to be found under the chin or even trying to occupy the same space as the chin. Allyn J. Thompson of New York writes that when making a tester, he discovered this inconvenient anatomical fact too late. He says: "I wish now that I had thought to keep the knife-edge stationary (except for the transverse motion) and move the slit, which would be more comfortable. I won't change now, but perhaps you could pass along the idea."

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Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful. The lists are not intended as bibliographies of source material for the articles. The references selected will provide supplementary information.

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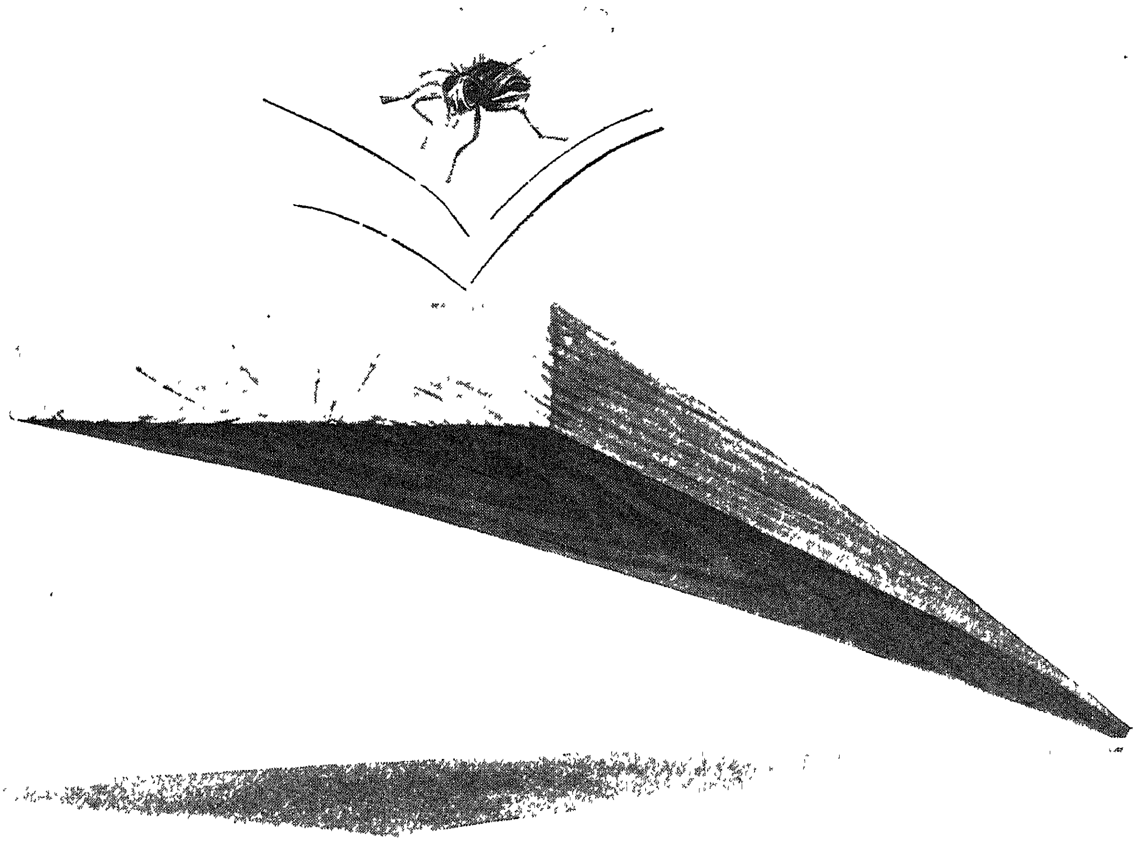

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LETTERS

Sirs:

With regard to Peter van Dresser's review of Dr. Robert H. Goddard's *Rocket Development,* which appeared in your April issue, I would like to point out the following:

Dr. Goddard was a doer. His interest was in making rockets work, rather than in speculating philosophically about them. And though he contributed the basic ideas on which others have speculated, his greater accomplishment was in laying the entire groundwork for our current understanding of rockets and their performance. It is curious that Mr. van Dresser seems disappointed that Dr. Goddard did not also find time to write books.

Dr. Goddard's first paper, *A Method of Reaching Extreme Altitudes,* published by the Smithsonian Institution in 1919, was the stimulus for the astonishing interest in rockets and interplanetary flight that appeared during the '20s in Europe, particularly in France, Germany, Italy and Russia. Hermann Oberth, of whom Mr. van Dresser speaks with admiration, published his book *Wege zur Raumschiffahrt* after a correspondence with Dr. Goddard in 1922. *Wege zur Raumschiffahrt* was published in 1923.

Mr. van Dresser suggests that somehow Dr. Goddard, though undoubtedly the "father" of modern rocketry, really had very little effect on current worldwide rocket developments. This is of course contrary to any simple observation of the facts. Dr. Goddard's influence was not transmitted through books, but through his patents, his confidential reports to the U.S. Navy and Army over a period covering two world wars, his reports to The Daniel and Florence Guggenheim Foundation, which supported his work, and the information he made available to licensees of his patents. More than 150 patents and patent applications in the field of rockets and jet propulsion bear Dr. Goddard's name, and are influencing rocket and jet developments continually.

There is, moreover, a group of men who were initiated to rocketry and trained under Dr. Goddard, who have had, and are having, a profound influence on the development of the rocket art. One of these outstanding men was Dr. C. N. Hickman, of the Bell Telephone Laboratories, who worked with Dr. Goddard during World War I, and who launched the whole American military program of dry-fuel rocket development which rose to such tremendous importance during World War II.

Another group of Goddard-trained men are currently at work in the Caldwell plant of Curtiss-Wright, developing rocket engines which carry out Dr. Goddard's principles, and are licensed under his patents. One of these new developments, a lineal descendant of the Goddard rocket motors, is the engine for the XS-2 supersonic experimental airplane, the approaching completion of which was announced recently by that company.

It is true that Dr. Goddard was a reticent man. He might have made faster progress otherwise—and again he might not. For in the period when Dr. Goddard did his greatest work his reticence, however annoying to some of us younger bloods who were trying to learn something about rockets, probably helped him concentrate fully on the problems at hand, and conserved the energies which he so single-mindedly poured into his work.

At any rate, the fact remains that he was able by 1940 to develop rockets which contained virtually all of the devices and inventions later used by the Germans in their V-2s. Before 1940

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Goddard had shot pump-driven, jet-steered, gyro-controlled rockets with fair experimental success—rockets which were smaller but otherwise surprisingly like the later rockets with which the Germans were to startle the world. There is good evidence—in addition to statements by some of the German engineers now in this country—that Dr Goddard's work was closely followed by the Germans, and that they put to good purpose the information so obtained.

It is nonsense to say that the material in *Rocket Development* has only historical or "antiquarian" significance. Dr. Goddard pioneered such current rocket ideas as transpiration cooling, swiveled motors, liquid-fuel jet-assisted takeoff, guidance of rockets by vanes in the jet, and the like. His experimental notes, as published in this book, and his rockets now on exhibit at the Smithsonian Institution in Washington, contain innumerable suggestions for engineers working in these areas, and for those working in many others.

G. EDWARD PENDRAY

New York, N. Y.

Sirs

I have just read the very fine article on aureomycin in the April number of *Scientific American.* May I call your attention to a very common error just for your own information?

I have recently returned from Australia after presenting a paper on the epidemiology of Q fever before the Seventh Pacific Science Congress in Christchurch, New Zealand. While in Australia, Dr. Derrick, who first recognized this new disease in man, and Dr. Burnet, after whom the causative organism was named, both assured me that "Q" was not for Queensland but rather for Query. The statement you made has so frequently appeared in American scientific literature that it is no wonder you also made it.

GORDON E. DAVIS

Rocky Mountain Laboratory
Hamilton, Mont.

Sirs:

The April *Scientific American* has just arrived, and as I expected, there would be something about Russell Porter. That biographical sketch is a masterpiece. I am sure Porter himself would love it, and we are all indebted to you for bringing to us the life story of a man universally loved and respected.

C. O. LAMPLAND

Lowell Observatory
Flagstaff, Ariz.

50 AND 100 YEARS AGO

JUNE 1899. "The development of rapid transit in Greater New York has been greatly stimulated by the passage of the bill authorizing the construction of a railroad tunnel from Brooklyn to the lower end of Manhattan Island. The present schemes contemplate a through route from an underground terminus in lower New York to connect with the extensive suburban railroad system of Long Island. It is also proposed ultimately to extend the tunnel beneath the Hudson River to connect with the Pennsylvania Railroad terminus in Jersey City."

"The Royal Institution of Great Britain, in commemoration of its centenary, has elected a number of American honorary members. The list includes Dr. Samuel Pierpont Langley, Secretary of the Smithsonian Institution and Prof. A. A. Michelson, of Chicago."

"The fastest speed for a long-distance journey was that accomplished by the winning carriage in the recent automobile race from Paris to Bordeaux, when a petroleum-driven carriage covered the distance of 353 miles in 11 hours 43 minutes and 20 seconds, an average speed of 30 miles an hour. This was a truly sensational performance. By sacrificing everything to power it is quite possible to build an automobile that will cover a straightaway mile at the rate of 60 miles an hour; and it has recently been reported from Europe that this speed has been attained more than once."

"The coal production and consumption of the world during the past 15 years are presented in some tables just prepared by the Treasury Bureau of Statistics. These show that while the United Kingdom is still the largest coal producer of the world, the United States is a close second, and if the present rate of gain is continued, will soon become the leading coal-producing country of the world."

"Last year a large international congress of chemists in the University of Vienna was opened with a classic discourse by the famous savant Buchner. According to the same, the yeast plants, as living organisms, do not, as was presumed heretofore, directly mediate the decomposition of sugar and formation of the alcoholic beverages, but it is chemical substances that produce the yeast-cell and cause fermentation. Since chemistry is continually becoming more perfect and productive in the field of synthesis, it is to be expected with certainty that in future this isolated chemical ferment will also be produced artificially."

"In the war of the Crimea, with 1,460,500 troops, there were killed in battle 53,870; died of wounds, 66,600; died of disease, 492,000. In the American war of 1861-5, in the Northern army, there took the field 2,336,000 troops; there were killed in battle 44,240; there died of wounds 34,006; there died from disease 149,240. In the American-Spanish war there took the field 274,717 troops; there were killed in battle 293; there were wounded 1,577; there died from disease 2,619."

"Prof. Dewar's success in liquefying hydrogen is bearing fruit. A company has been formed with a capital of $150,000 to determine whether steel can be cast in a vacuum or not. It is hoped, if the plan is successful, that the air bubbles that now cause flaws and weaknesses will be done away with, and that the metal which is produced will be wonderfully homogeneous."

JUNE 1849. "Mr. E. Jordan, of West Cummington, Mass., has made an improvement on the Fountain Pen, whereby the ink is supplied continually in the same quantity from the fountain independent of the quantity in the fountain. If there is any ink in the fountain at all, it will be transmitted to the pen in a gradual even stream."

"Congress has made an appropriation for an expedition to determine the parallax of the planets, by observations on Venus and Mars, made at places situated north and south of the equator. The telescope has been completed and the result is in the highest degree satisfactory."

"Patent granted to A. Lincoln of Springfield, Ills., for improved method of lifting vessels over shoals, May 22, 1849."

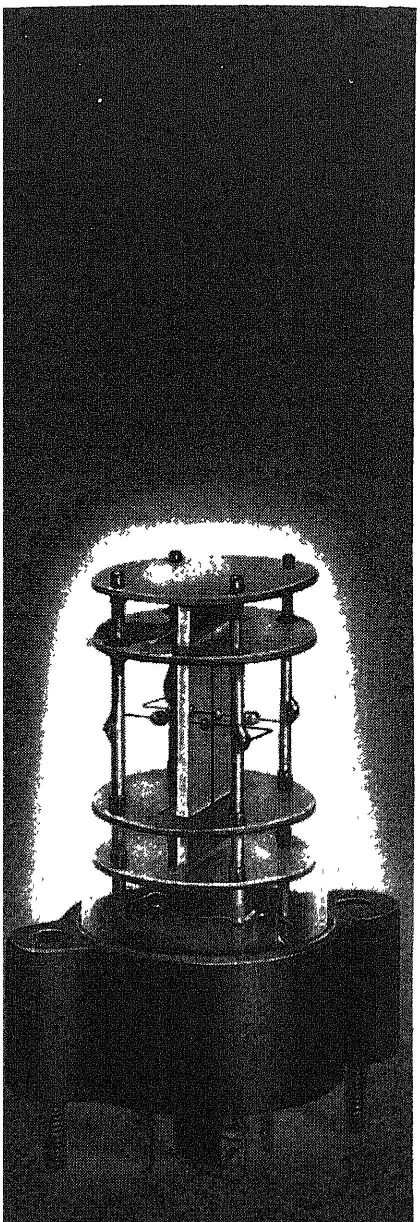
"The humble and apparently insignificant Moss is an active agent in some of the most important changes of nature. By its great absorption of moisture, its decay and subsequent revival in succession, the hardest rock, upon which not even a blade of grass could grow, becomes covered in the course of years with a stratum of fertile soil, supporting the most luxuriant trees."

"Professor Schumacher, Altano, announces by a circular of the 11th of May the discovery of another new planet. It resembles a star of the 9th or 10th magnitude. The motion of the planet was retrograde, and it was approaching the equator. This is the ninth new body (including planets' satellites) which has been added to the solar system within the last four years."

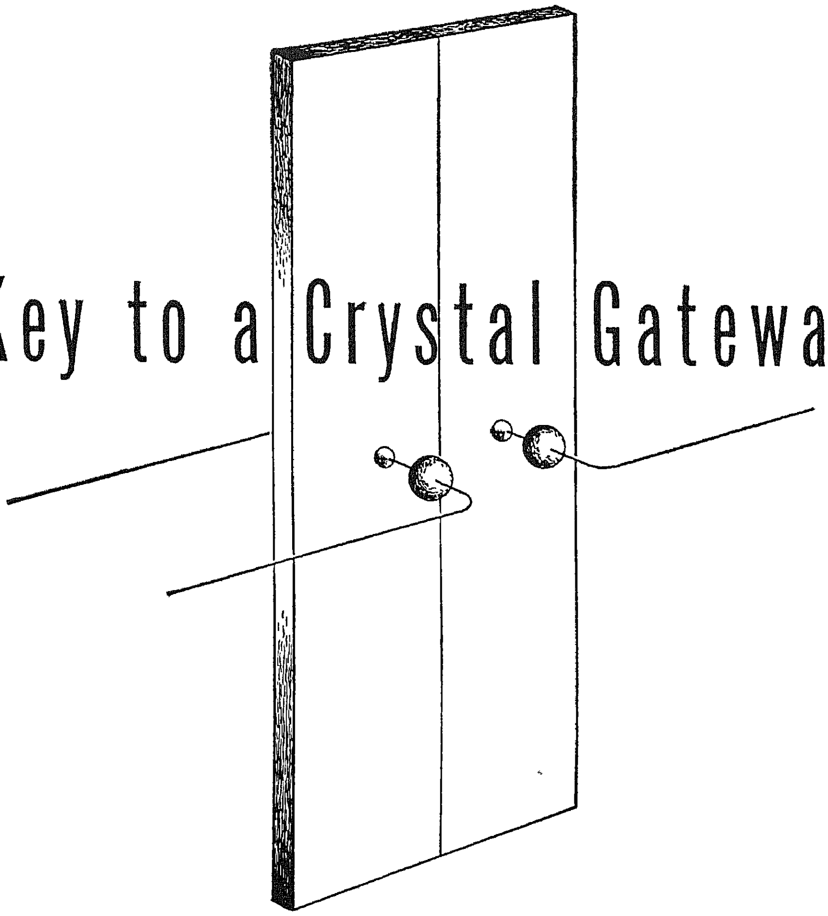
"From what prior condition must we imagine the present solar system to have been evolved, in order that it may contain the arrangements and dispositions we have seen in it? The solar system may have come into being out of some nebulous mass, which has gradually condensed according to the simple law of gravity. In order to understand what may have taken place, we must follow the condensation of this nebulous mass, and enquire what, according to known laws, would take place; we find that our system is just such an one as must result of necessity from laws acting under those circumstances."

"There is a great amount of electricity produced by the interior processes of the human body, but how much none can tell, as only a small portion can appear in a free state on the surface. The juices of the flesh or muscle are constantly acid while the blood circulating through the arteries or veins, is alkaline. An acid and alkali with a membrane between them, are capable of causing a current, the acid being positive and the alkali negative, so that the blood would from this cause have a negative charge and the flesh a positive charge."

"If a magnet be made very powerful by means of a galvanic battery, all substances whatever, if made into bars and suspended over it by a delicate thread, will point either to the north and south poles or else in a direction equally between them, that is, east and west. Gold and silver point in this latter direction, as also do many others. This has lately been discovered by Faraday in London, who has named the influence Dia Magnetism. In order to produce it, the artificial magnet must be very powerful."



Key to a Crystal Gateway



Above is a coaxial circuit crystal in its glass enclosure. At right the crystal is shown, 3½ times actual size, with connecting wires soldered in position. Weights on wires reflect energy back into crystal, so cut losses.

How would you solder a wire to a crystal? This must be done for most of those wafer-thin plates of quartz used in electrical circuits. They play a big part in the myriad-channel telephone system that utilizes coaxial cables.

This is how Bell Laboratories scientists solved the problem: A spot of paste containing silver is deposited on the crystal and bonded to it by oven heat. The crystal is then vapor-plated with a thin layer of silver. Then a fine wire is soldered to the spot by a concentrated blast of hot air. The result is a rugged electrical connection to the surface of the crystal which does not interfere with its vibrations.

Sealed in glass tubes, the crystals are precise and reliable performers in the telephone system. Each is a crystal gate to a voiceway, separating *your* conversation from the hundreds of others which may be using a pair of coaxial conductors, at the same time.

This spot of paste, this tiny wire, this puff of air are among the tremendous trifles which concern Bell Telephone Laboratories in finding new ways to improve your telephone service

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THE COVER

The painting on the cover reproduces a part of a painted limestone bas-relief on the tomb of the Pharaoh Harmhab, a ruler of the 18th Egyptian dynasty who lived around 1350 B.C. The bas-relief shows a group of Negro captives guarded by Egyptian soldiers (*see page 40*). The standing figures who bear clubs are the guards. At the right a scribe keeps tally of the prisoners. The hieroglyphs at the upper left are part of an account of the capture of the prisoners. Harmhab was a soldier who, although he was not in the royal line, attained the throne, married a princess and carried on numerous military expeditions in surrounding countries. Among his booty were the captives depicted on his tomb. In this type of bas-relief, the background was not chiseled deeper than the figures. Deep lines were cut into the stone to outline the figures and give them depth. The faded earth pigments now remaining on the carving have been restored in the painting to their original brightness. This bas-relief is now in the Museo Civico of Bologna, in Italy.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
12-15	Irving Geis
17-21	Eric Mose
22-23	A. Szent-Gyorgyi
24-25	G. Rozsa
31	Eric Mose
32	David Schoenberg, Royal Society Mond Laboratory, Cambridge University (*top*), Sovfoto (*bottom*)
35-36	Eric Mose
39	Arthur D. Little, Inc.
40-43	New York Public Library
45	Adolph Brotman
46-47	John Tyler Bonner
48	A. M. Zarem
49	Irving Geis
50-55	Ben Shahn
56	William Auerbach-Levy
60-61	Ralph Ingels Fenn
62-63	Robert L. Waland

What GENERAL ELECTRIC People Are Saying

E. E. JOHNSON,

Manager of Engineering, Apparatus Department

ALLOY RESEARCH: The average steam turbine in use 25 years ago required the burning of $2\frac{1}{2}$ pounds of coal per kilowatt-hour at the switchboard. Today the average is $1\frac{1}{2}$ pounds of coal, and our best turbine-generator requires only $\frac{3}{4}$ pound.

This has been the result of much painstaking work by many people, particularly in the field of high-temperature, high-strength alloys. I have confidence that the trend will continue because, in the case of metallurgy alone, fundamental research in the structure and formation of alloys is being pursued intensively . . . Indications today are that we shall be able at least to double the strength and ductility of steel alloys and at the same time use a lower percentage of critical materials than has been necessary up to the present . . .

A well-planned program which will cover a period of years has been started, out of which should come greatly increased knowledge of alloying so that, for example, whereas we now design commercial gas turbines for an inlet temperature of 1400 F, it should be possible in the next few years to raise this temperature appreciably, with attendant increase in turbine efficiency. Likewise, steam boilers and steam turbines which now have a practical upper limit of temperature of 1050 F may in the next few years be operating at temperatures considerably higher, and this would mean a greater saving of fuel to our country.

San Francisco Electric Club,
March 21, 1949

★

R. W. PORTER,

Aeronautic & Ordnance Systems Divisions, Apparatus Department

ROCKETRY: Our job in 1949—and I'm afraid for several years after that—is to take the "magic" out of rocketry. However, I'm glad to be able to report that real progress is being made.

Theoretical values of specific impulse have been calculated for most of the interesting propellant combinations. Tests show that we can expect to obtain at least 90 per cent of this performance in practical motors. Experience in making and handling propellant materials is being accumulated rapidly, especially in the case of liquid hydrogen, metallic hydrides, fluorine, and hydrazine.

Test facilities have been built capable of testing rocket motors many times larger than the V-2. Because of the terrific temperatures involved, the matter of heat transfer is vitally important, and here, too, some progress is being made, both in understanding the phenomena and in designing the motor so it will run cool.

Information about the performance of electronics equipment under missile flight conditions, and about the nature of the upper atmosphere, is being gathered by frequent flights of the German V-2's, Aerobees, and other test vehicles. At least half a dozen sizeable supersonic wind tunnels will go into operation this year, and we will begin to use new mathematical machines capable of handling the complicated equations of missile flight dynamics.

Yes, we're really getting started. But it will be a long time before a rocket engine can be designed from a handbook like a motor-generator, or a supersonic missile with the certainty of a radio set.

Eta Kappa Nu,
New York, N. Y.
January 31, 1949

★

W. C. WHITE,

Electronic Engineer, Research Laboratory

ELECTRONICS START: General Electric's entry into the electronics field and the many benefits which have accrued therefrom are a good example of serendipity.* Dr. Irving Langmuir, shortly after 1910, began an investigation to promulgate the basic physical laws underlying the many relationships that exist between the properties of an incandescent tungsten filament in a high vacuum. This involved relationships among current, voltage, length and diameter of filament, its temperature, and the loss of energy through radiation per unit of area.

Somewhat before that time Professor O. W. E. Richardson of Princeton University had published the results of some experimental work on the electron emission from tungsten in a high vacuum. This appealed to Dr. Langmuir as being one of the properties of a tungsten filament and that it probably should be included in his information available on the subject. His experimental work to confirm and amplify the results of Professor Richardson led to the thorough understanding of what we now call the space-charge effect and the mathematical relationships involved. His work thus provided a sound engineering basis from which high-vacuum, thermionic-cathode electron tubes could be designed. That work put General Electric into the field of electronics . . .

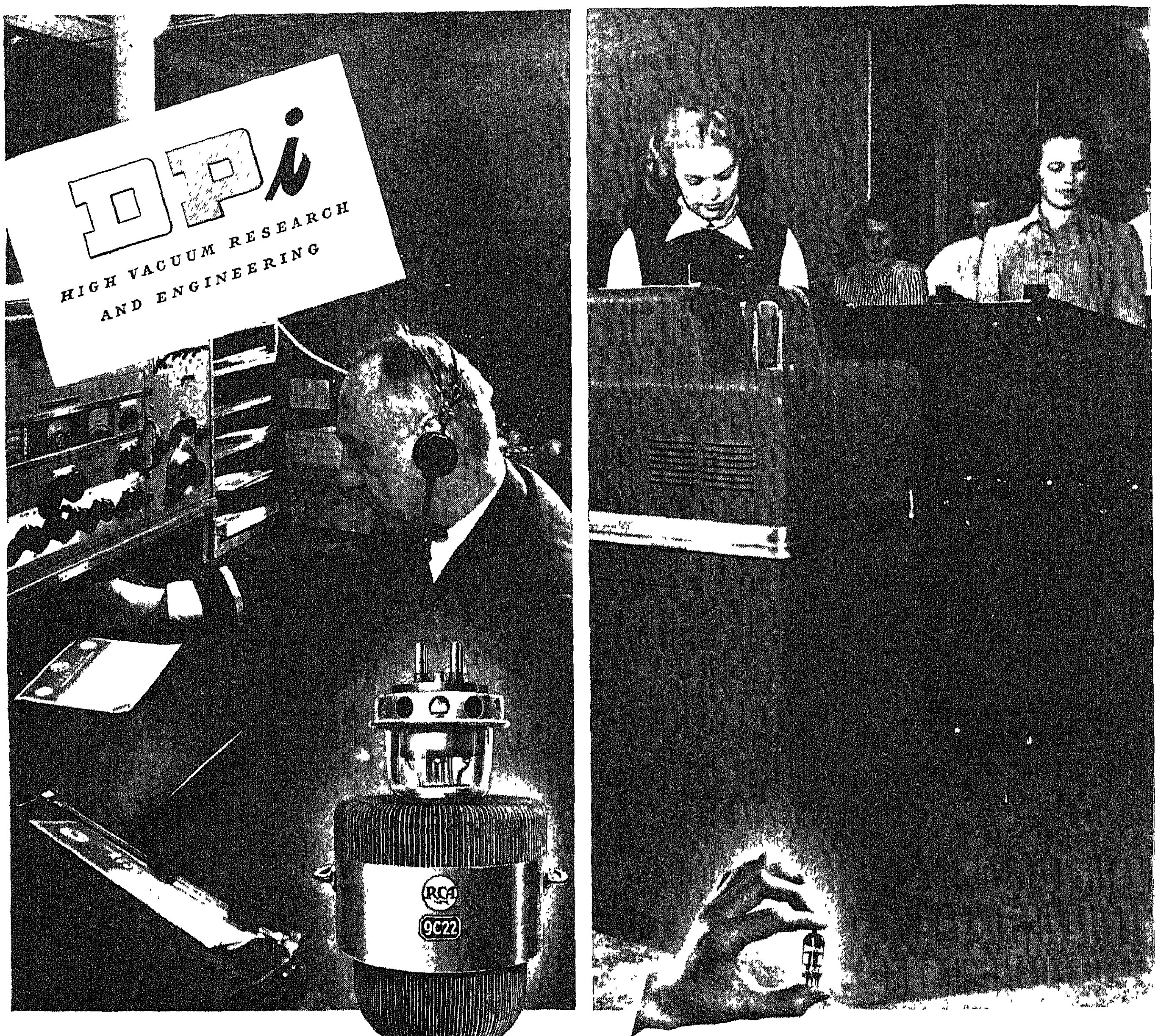
Colgate University,
October 12, 1948

* The gift of finding valuable or agreeable things not sought for.

27 Years Ago

ELECTRICAL AGE: We call this the electrical age, but it isn't. The electrical age has scarcely begun. When it comes, electricity will do for everybody all that it can do for anybody. And it will do innumerable things of which we have never dreamed. For the electrical age is yet to come. It will be a great age.

Charles P. Steinmetz
1922



Longer Life for Giant and Midget

THE "giant" electron tube shown above is made in the Lancaster, Pennsylvania plant of the Radio Corporation of America. Said to be the largest forced-air-cooled radio transmitter tube yet made, it can send radio waves around the world. Capable of handling an input of 100,000 watts, this tube requires exceptional engineering and manufacturing skill for its production.

The "midget" tube is an electronic relay to replace mechanical relays in International Business Machines. As many as 300 of these tubes are used in some IBM accounting machines. A notable achievement of electronic engineering, they cut down the heat factor and permit faster machines of more compact design.

The higher the vacuum in electron tubes, the better they work, and the longer they serve. DPI high vacuum pumps have been built into ingenious production line machines designed by RCA engineers to exhaust electron tubes to high vacuum at greater speed.

New ways of using high vacuum are constantly being discovered. In high-vacuum stills, materials once thought non-distillable are being fractionated—made into profitable commercial commodities. In high-vacuum chambers precious vaccines are given longer potency because of better dehydration. High-vacuum coaters are depositing metallic coating on wood, paper, cloth, glass, and plastics.

Heads of businesses in all fields should learn what high vacuum may do for them—in making a better quality product, in cutting costs, in converting waste materials into valuable commodities. We invite inquiry.

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SCIENTIFIC AMERICAN

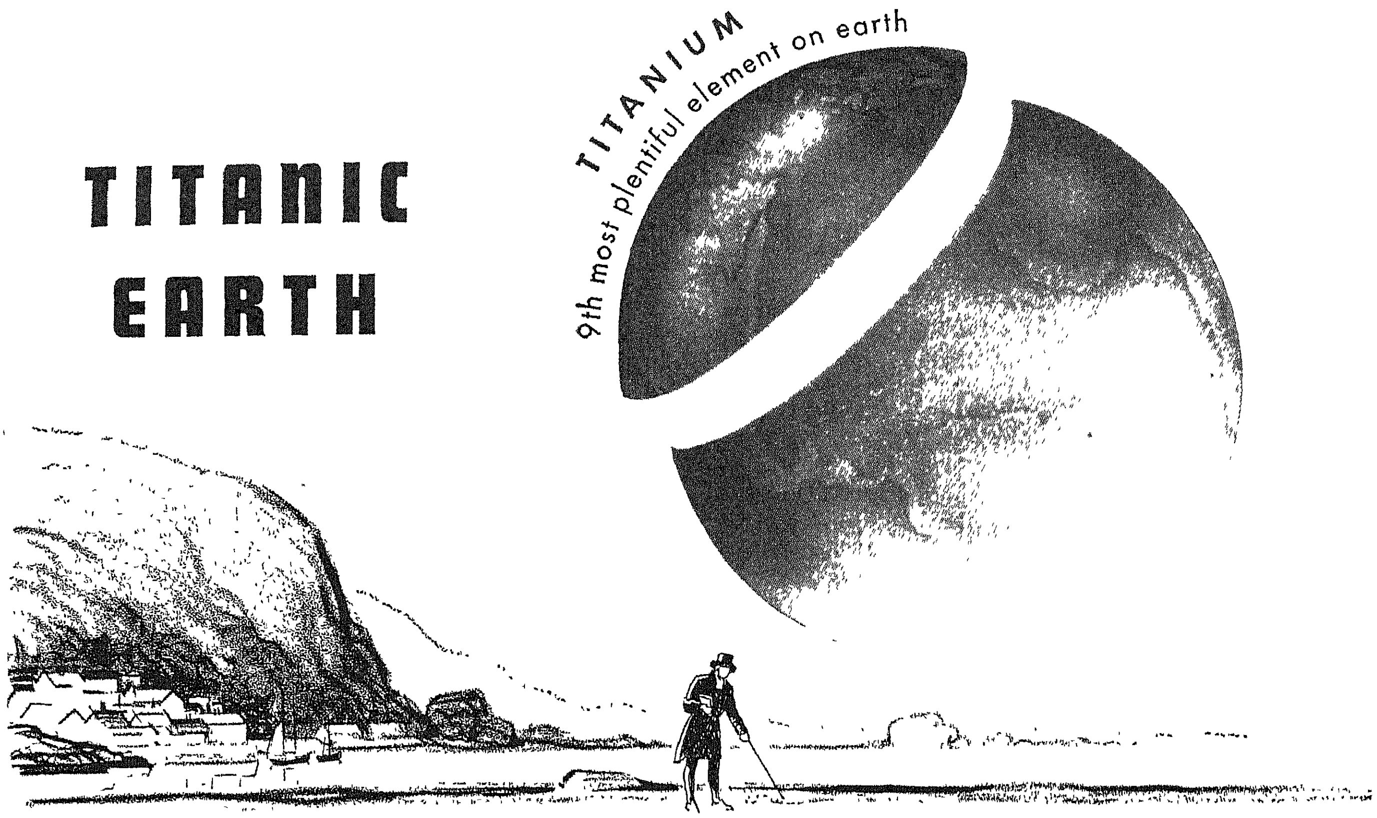
Established 1845

CONTENTS FOR JUNE 1949 VOLUME 180, NUMBER 6

ARTICLES

DEPARTMENTS

TITANIC EARTH



TITANIUM DISCOVERED

Back in 1791 an English clergyman, William Gregor, who liked to stroll and think on the beaches of Cornwall, became curious about the black sand he saw there. This gentleman of the cloth was also an amateur chemist and in this sand he discovered a new element. Almost coincidentally an Austrian named Heinrich Klaproth (also discoverer of uranium and zirconium) extracted the same thing from rutile and named it "Titanic Earth" for the mythical Titans. Hence our name Titanium.

Thereafter titanium was found in various places including the Ilmen Mountains of Russia (ilmenite) but although it is the ninth element in order of earthly abundance, it remained a mere laboratory curiosity until 1908.

TITANIUM OXIDE

At that time Dr. A. J. Rossi, expert in the reduction of metals, mixed titanium oxide with salad oil to make a white paint. In another 10 years a pure oxide was being produced which quickly won success as a pigment. Paint, false teeth, face powder, tires, shoes, glassware, textiles, inks, plastics, paper consumed an increasing tonnage of titanium oxide but still the pure metal was beyond industry's reach.

TITANIUM METAL & NATIONAL RESEARCH

Titanium is an affectionate metal, over fond of oxygen and nitrogen when at high temperatures. Even a fraction of a per cent of either makes titanium of little value as a structural material. Until recently there was no means of preparing titanium metal in a form sufficiently free of these elements to indicate any potential commercial value. Dr. W. J. Kroll of the Bureau of Mines has initiated many of the recent developments in titanium metallurgy by finding a means of preparing powdered titanium metal.

Only by exclusion of these gases can it be kept from embrittling combinations and when Remington Arms Company, a Du Pont subsidiary, laid its plans to produce metallic titanium in cast and rolled shapes, they knew that at National Research Corporation they could find the knowledge of vacuum technique that they needed.

The melting and casting of titanium was a natural for National Research We planned the process, designed the equipment and installed it. Today this National Research Corporation pilot equipment is handling the highest quality of commercial metal — not much compared with aluminum — nothing at all compared with steel — but so promising that millions will be spent by the industry within a few years to increase the quantity and lower the price

USES OF TITANIUM METAL

Titanium stands fourth in abundance among the structural metals and there is plenty in the U. S. A Tremendous strength, light weight, and remarkable corrosion resistance (comparable only to that of the noble metals) is a unique combination. Coming at a time when long-sighted people are viewing our metallic resources with alarm, it has an assured future. With the price pulled down to a few dollars a pound or less, titanium will be of primary importance to manufacturers of aircraft, automobiles, electric devices, gas turbines, superchargers, marine hardware, rockets, optics, jewelry.

WHAT NEXT?

So, with the help of National Research's high vacuum know-how, another material has been taken from the test tube to the factory. Where else can good men and ideas help — where can they help you? At National Research the best in brains, organization, equipment, and an unequalled accumulation of unique experience are available.

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SCIENTIFIC AMERICAN

JUNE 1949 VOL. 180, NO. 6

NATIONAL HEALTH INSURANCE

The proposal now before Congress has generated more heat than light. What is it, and what are the alternatives its opponents have proposed?

by Michael M. Davis

WHEN this issue of SCIENTIFIC AMERICAN comes from the press, committees of the Senate and the House will be conducting public hearings on the national health insurance bill. For 11 years the question of what is to be done about the rising costs of medical care has been before Congress The issue is inescapable. With every year the American people's concern about the matter has increased. So clearly is this concern becoming transformed into demand for action that this year those who oppose national health insurance have introduced alternative proposals that are also being considered in the current hearings.

While the health insurance proposal has been hotly discussed, so few people are acquainted with the actual provisions and meaning of the bill that perhaps the most important requirement for intelligent debate of the issue is greater public understanding of the proposal itself.

The first thing to be made clear is that the measure before Congress, called the National Health Insurance and Public Health Bill, is not "socialized medicine." Indeed, after a generation of experience with health insurance, physicians in the democratic countries of Western Europe, all of which have national insurance plans, have come to regard it as a bulwark of the independence of the medical profession, in contrast to socialized medicine of the Russian sort.

Under the present bill, doctors would remain independent practitioners; they would not be employees of the government. Hospitals would retain their autonomy. Patients would be as free to choose their doctors as they are now. The general operation of the plan would be as follows.

All employed and self-employed persons in the U.S, with few exceptions, would pay regularly into a national health insurance fund, for most people the payments would be deducted from earnings along with Social Security contributions. Employed persons would pay 1.5 per cent of their earnings (on that portion of their earnings up to $4,800 a year). Employers would match their payments. Self-employed persons, *e.g.*, businessmen and professional workers, would pay three per cent. The Federal government, after collecting these funds, would allocate them to the states, which in turn would distribute them to local areas according to plans made by the states. Either the states or the local agencies would pay the medical and hospital bills of the insured persons and the dependent members of their families.

All these people would be entitled to complete medical care from general practitioners and specialists, hospital care up to 60 days a year, laboratory and X-ray services, eyeglasses, medical appliances, and expensive medicines when prescribed by a physician. The plan would also provide a very limited amount of dental care and home nursing.

The bill guarantees doctors complete freedom of choice. They could join the system or not, as they wished, could accept or reject any patient, could practice wherever they liked. If they entered the insurance service, they would decide for themselves how they were to be paid from the insurance fund—whether by fees for services, by a part-time or full-time salary, or by a blanket per capita fee for each person selecting the doctor as his regular physician. Through their representatives the doctors would negotiate the amounts of their payments with the state or local health insurance agency. As for hospitals, the bill guarantees them adequate payment for their services and freedom from government interference in their administration

The administration of this program would be carried out primarily at the local level. There would be a five-man national board with an advisory council of lay and professional people. This board would be appointed by the President as part of the Federal Security Agency, but its powers would be limited to the collection of funds and their allocation to the states, the approval of state plans, and the maintenance of general standards. The actual carrying out of the program in each community would devolve on a board of local citizens, including representatives of the medical profession and hospitals, and working under the state's plan.

How would it work for John Doe, the patient? Doe (or his wife or children) could visit or call any doctor of his choice when he is sick, as he does now. When necessary, his doctor would refer him to a specialist, arrange for his ad-

mission to a hospital, or order any laboratory or X-ray tests required. But Doe would get no bills, the insurance fund would pay the doctor or hospital directly for all the services he received.

What if Doe could not be a contributing member of the system, because he had no income? He would receive these services if the local or state welfare department made the insurance payments for him. Thus doctors would be paid for most of their present charity work.

HOW would it work for Dr. Richard Roe, a general practitioner in a middle western town of, say, 20,000 people? After enactment of the law there would be a period of about two years before it began to operate, during this interval Dr. Roe would decide whether he wanted to take part in the plan. His decision would probably depend greatly on what his regular patients did. Presumably most of his patients, and some others who previously had not had a regular doctor, would choose him as their family physician under the plan, in which case he would be likely to join up. If some well-to-do patients chose to make private arrangements with him outside of the insurance system, he could also accept them.

Dr. Roe and other doctors in his community would then decide, probably at meetings of their county medical society, how they wanted to be paid for their insurance patients. The majority might vote for a fee-for-service system such as they had been accustomed to in the past. Dr. Roe probably would go along, though he would not be required to; he might choose to take a salaried post in a hospital, in industry, or as a member of a group-practice unit. Meanwhile a state committee of physicians would have been discussing over-all procedures and rates of payment with the state health insurance agency. They would draw up a schedule of fees, adjusted to localities or classes of localities and to various services. If Dr. Roe chose to accept the fee-for-service plan, he would be paid according to this schedule. Once the terms were arranged and the plan went into operation, he would go on practicing just as he had before. He would usually serve only his regular patients, but if he were called to treat someone else in an accident or other emergency, he would receive the regular payment from the insurance agency. He would know that his patients could change their doctor, just as they can now.

What about Dr. John Smith, a surgeon in a large city? As a specialist, certified as such by the American Board of Surgery, he would get most of his cases, as he does now, by reference from other physicians, usually family doctors. But a patient might come to him directly when necessary. As to remuneration, Dr. Smith might be a young salaried surgeon on a hospital staff, if he were an independent practitioner, he would receive a fee for each operation. Even if Dr. Smith were not certified as a specialist by a national specialty board, under this law he would be entitled to receive payment at specialist rates provided he were recognized as a specialist by an appropriate state professional body.

Voluntary health insurance plans which, like Blue Cross, provide or organize services, could continue under the national system. Commercial insurance and other plans paying only cash indemnities could continue by providing benefits supplementing those of the national plan. Insurance plans which have their own staffs of doctors—as do medical cooperatives and many plans sponsored by industries, unions and farmers' organizations—would be encouraged.

Besides health insurance, the bill provides important measures for increasing medical personnel and facilities and for improving their geographical distribution. The U.S. has more doctors in proportion to population than any other country in the world, but they are very unevenly distributed. For a generation or more the cities have been drawing a disproportionate number of physicians, and most rural districts have been losing them. Rural and poor urban areas are also short of dentists, nurses, hospitals, and local public health departments. In the nation as a whole we need more professional personnel and more hospital beds. The bill sets up programs to help remedy these shortages.

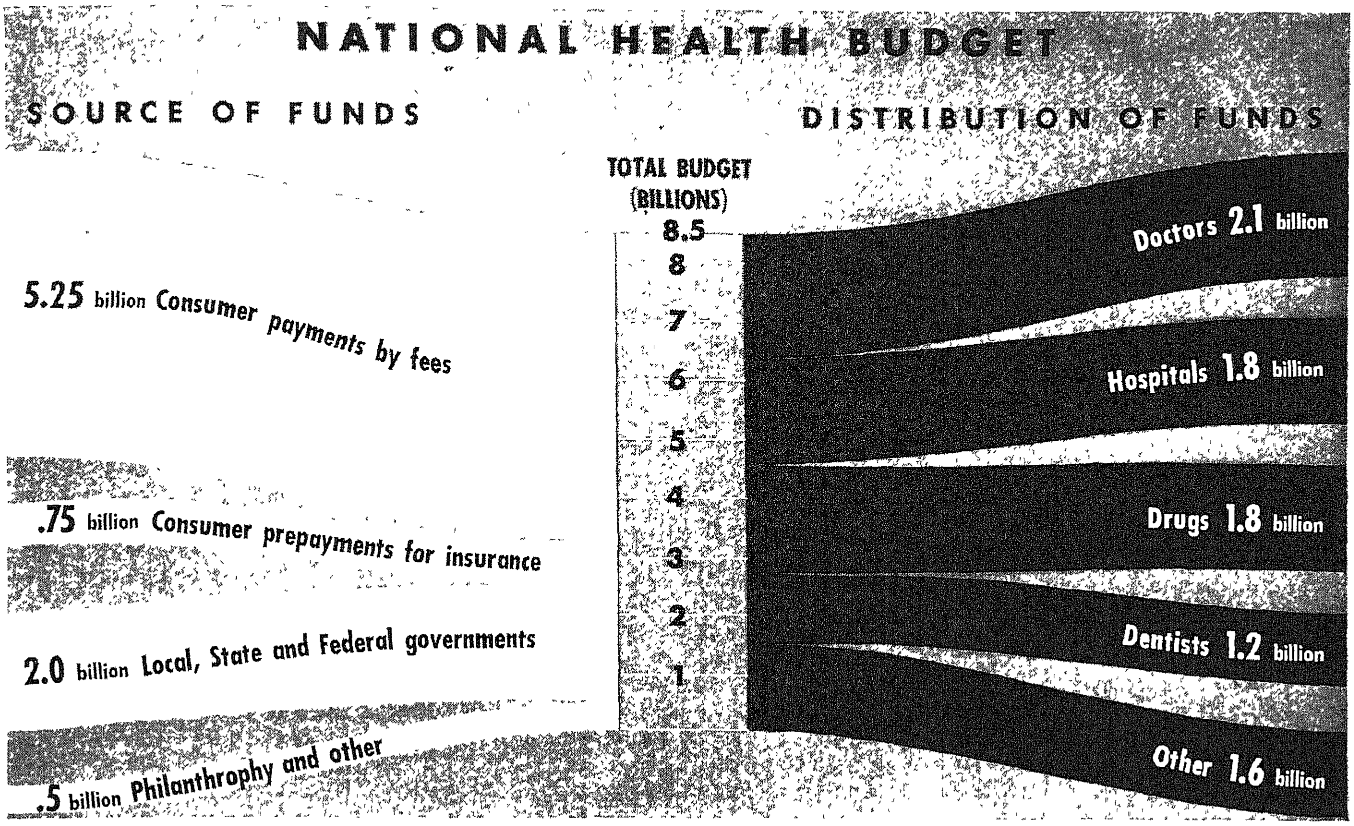
Such is the program proposed in the bill. Before considering the pros and cons and the current alternative proposals, it is desirable to examine the situation that has called it forth.

WHEN I was a boy, living on the West Side of Manhattan, we had a family physician who lived in the next block. He looked after my parents and their six children all by himself. We hardly ever thought of going to a hospital, and neither we nor our doctor knew anything of X-rays or cardiograms or any but a few simple laboratory tests. Today a dozen different specialists are called in to care for the smaller families of my parents' descendants. Medicine is now far more efficient: it saves more lives, alleviates more suffering, and has greatly prolonged the life span. But its cost is correspondingly higher. There are many more $50, $500 and $1,000 illnesses than formerly. And because sickness costs cannot be predicted by the individual, even the 20 per cent of American families with incomes over $5,000 may suffer a severe shock to their finances in a major illness, while families with lower incomes may have as their only alternatives charity, debt or disaster.

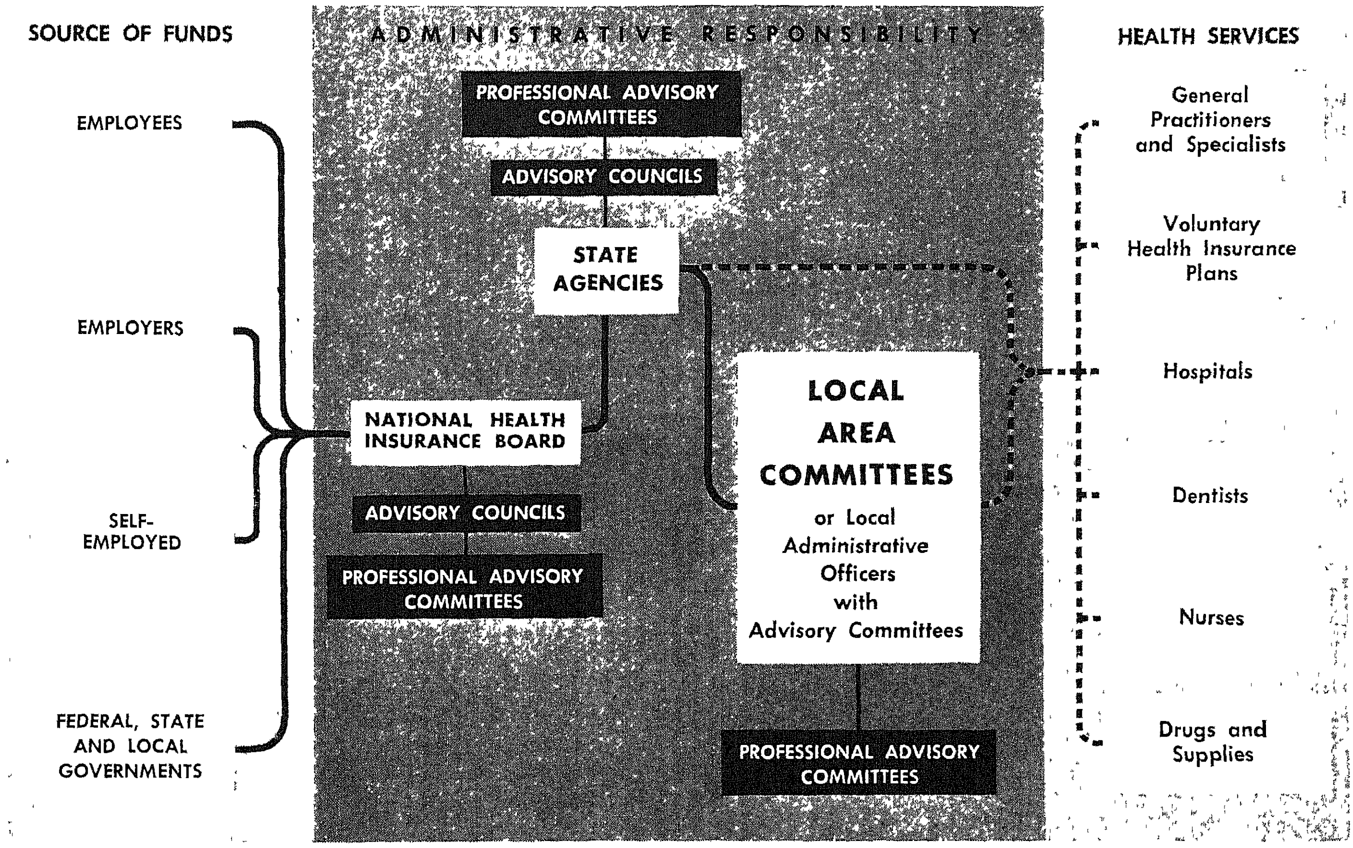
As I sat listening to the radio recently, a smooth, professional voice came over the air on a nation-wide network "Suppose you wake up tonight with a pain in your right side, and before morning you are on a hospital operating table having your appendix out. How are you going to pay the $250 which your hospital and surgeon's bills will come to?" The speaker was not a critic of our system of medical care but a commercial announcer for a large insurance company. The fact that the company was buying expensive radio time to advertise its health policies is excellent proof, if proof were needed, of the importance of this problem to the majority of the American people. My fellow-listener, a physician who has been practicing medicine for 40 years, added a footnote to the announcer's words: "Yes, but I wish he would talk about health service instead of just surgical emergencies, what we need is health insurance plans that encourage people to go to a family doctor at the first sign of illness or for checkups when they have no illness."

The basic facts about medical economics in the U.S. were firmly established in a five-year study between 1927 and 1932 by the Committee on the Costs of Medical Care, which was headed by Dr. Ray Lyman Wilbur and supported by eight large foundations. The study determined what American families at various income levels spent for each item of medical care; what services they needed and what they got, what government agencies spent for medical services; what hospital facilities were available; what doctors' incomes were; and how all these matters were related to the size and location of communities. From its 27 fact-finding volumes the Committee derived the conclusion that future medical service in the U.S. should be built on the economic base of pooled risks—chiefly through voluntary health insurance—and on the professional base of group practice instead of the traditional solo practice.

The American Medical Association at the time described these recommendations as "socialism and communism, inciting to revolution." The Committee's findings in 1932 interested few except doctors and students of the subject. But its reports have been germinal in the march of events. Within six years health insurance entered the political arena. Today the AMA supports voluntary health insurance as an alternative which it considers preferable to a national system. Meanwhile governmental activities in health have grown to a degree not generally realized. Expenditures for health services by the Federal, state and local governments now aggregate $2 billion a year. The largest items are for state mental hospitals and the Federal medical service of the Veterans Administration. The Federal government has been making grants to the states since 1946 for hospital construction, and mem-



THE PRESENT COST of medical care in the U. S. is approximately $8.5 billion per year. This sum is paid by the individuals and institutions listed at the left side of the diagram above. It is paid for the services listed at the right. This budget would remain about the same under any plan of national health insurance, except that the consumer payments by fees and the consumer prepayments for insurance (*left*) would be lumped together.



THE PROPOSED FRAMEWORK of national health insurance has been erected between those who need medical care and those who supply it. Insurance payments are made to the National Health Insurance Board, advised by both laymen and physicians. This works with state agencies which make actual payments, preferably through a local area committee. Dotted lines at right indicate that medical services are not integral part of plan.

bers of both parties in Congress are now sponsoring special bills for extending public health services, for maternal and child health, for aid to research, for assistance to medical and allied professional schools, and so on.

As a result of a National Health Conference called in 1938 by Franklin D. Roosevelt, Senator Robert F. Wagner in 1939 introduced the first national health insurance bill. Since then most successive Congresses have held extensive hearings on a series of such bills. These measures have had an interesting evolution. Their trend has been toward greater and greater decentralization of administration, with more responsibility on the states and localities and less on the Federal government. The successive bills have also broadened from a health insurance measure into a comprehensive national health program. These and other issues are thrown into relief by the alternative proposals now before Congress One of these is a bill sponsored by Senator Robert A Taft and two Republican colleagues. Another is the voluntary health insurance bill sponsored by Senator Lister Hill of Alabama, two Democrats from border states and two Senators of the liberal Republican wing. The third is a bill sponsored by Representatives Jacob K. Javits, Christian A. Herter and others. As a result of the presentation of these alternatives, Congress for the first time faces politically realistic choices among policies of national action to deal with the costs of medical care.

Senator Taft's bill would make Federal grants to the states, to be administered by the states, to pay for medical service for persons who cannot themselves afford "all or part" of the costs of such care. Senator Hill's bill is a state-aid plan also, but it would require the states to use the Federal funds through voluntary health insurance plans. (Under the Taft bill this would be permissible but not obligatory.) Persons eligible because of their limited means could be enrolled as members of such plans free or at reduced rates, and the costs of their care, when needed, would be paid for them. But this bill would cover only hospitalized illness and diagnostic work in a hospital or clinic.

Both of these bills would determine the eligibility of people for help through some form of means test. Both of them—according to their critics—would set up the Federal and state administration in such a way as to give control to the professional groups or to the particular types of insurance plans that would receive most of the money.

In contrast, the national health insurance bill provides for bodies on local, state and Federal levels in which the professions and hospitals always have representation, but in which the members representing the consumers of medical service always have a majority when dealing with financial and administrative matters. On the other hand, matters which are wholly professional must be dealt with only by professional persons. The most successful of our American medical enterprises, the voluntary hospital, has tested for a generation and more the principle of lay control combined with professional freedom. The typical American hospital is owned and managed by a board of trustees composed wholly or mostly of laymen They appoint the medical staff, but they do not direct doctors how to diagnose and treat patients They do approve and can enforce the professional standards of the institution as outlined by the doctors. This tested pattern of lay-professional relationships is followed by national health insurance.

Representative Javits' bill seeks also to work through voluntary insurance plans, but would follow the pattern of national health insurance by requiring all approved plans to charge their members a percentage of earnings. Nearly all the existing plans now charge a flat rate irrespective of the subscriber's income.

Thus these bills raise before Congress and the country the issue of whether voluntary insurance, with or without government aid, can do the job that the country needs and the people clearly want to have done.

Voluntary health insurance has grown with extraordinary rapidity in the U.S. Twenty years ago perhaps a million persons were enrolled in such plans. Now the number is at least 50 times greater. But how broad are the medical services provided or paid for by these plans? In other words, how much as well as how many do they serve? The Committee on Research in Medical Economics has issued this summary as of 1949.

1. About 3.5 million persons are covered for comprehensive medical care, including preventive treatment as well as care in ordinary and catastrophic illnesses, hospitalization and other services.

2. About 27 million persons are covered for both hospitalization costs and physicians' services in hospitals. If this insurance represented full coverage for these services, it would pay about 35 per cent of the average family's total medical expenses. In practice, the insurance payments are usually considerably less than the actual costs to the patient.

3. Approximately another 27 million persons are covered by hospitalization insurance alone Often this insurance does not pay the full hospital bill. When it does, it covers about 21 per cent of the average family's medical costs.

These figures explain why Bernard M. Baruch told a large medical gathering in New York City a year and a half ago that voluntary insurance was "good, but not good enough." A national program of combined Blue Cross and Blue Shield coverage, such as the Hill bill envisages, would be economically insufficient, protecting against too small a proportion of total medical costs, and medically inadequate, tending to promote hospitalization, the most expensive form of care, and doing nothing to encourage the early treatment or prevention of illness.

Moreover, the legislatures of 22 states have passed laws which prevent or greatly hamper the establishment of any voluntary plan not controlled by the medical societies These laws typically provide that no voluntary plan can operate in any area unless 51 per cent of the physicians in the county approve it, and that a majority or all of the members of the governing board of any plan must be approved by the state medical society. In many places, county societies have applied pressures, essentially boycotts, against doctors who joined or considered joining the staff of a plan sponsored by a union, a cooperative or other association of "consumers."

What would national health insurance cost? On the most reliable estimate the Administration bill would cost $5.5 billion a year. For the services it embraces the American people now spend $4.4 billion a year. (Counting all other services, such as medicines and dental care, the nation's total medical bill is over $8 billion.) Thus the bill would provide about 25 per cent more medical service than the population is now getting. These services are clearly needed. And the $1.1 billion additional expenditure would mean larger incomes for doctors and the reduction or elimination of hospital deficits. Moreover, by stabilizing the purchasing power for medical care and distributing it more widely, the plan would support doctors and hospitals in areas that now cannot maintain them.

It must be borne in mind that the average American family is now spending three per cent of its income for doctors' and hospital care (plus one per cent additional for medicine, dentistry and incidentals). Thus even if employers passed on all of the cost of their 1.5 per cent contribution to consumers in the form of higher prices, the resultant three per cent contribution by consumers for health insurance would mean for most families no greater expenditure than they are making now.

A small but distinguished group of physicians, while disagreeing with the AMA's view that national health insurance would lead to "the ultimate socialization of the nation," objects to the plan on the ground that it would not produce service of sufficiently high quality. This group, headed by such leaders as Dr. Edwards A. Park of Baltimore and Dr. George Baehr of New York, wants an evolutionary development of health insurance combined with group medical

practice But it is not easy to see how this is to be brought about Actually the evolution of the last 20 years has been in the direction of medical impoverishment of the rural areas, and entrenchment of the forces that prevent the development of group practice in conjunction with insurance. These forces are still at work and tend toward extension of the restricted and proprietary types of voluntary insurance, the limitation of group practice and the provision of specialized, poorly coordinated programs of tax-supported medical services. These developments do not appear likely to improve the organization and distribution of medical care.

The objection is raised that the removal of the economic barrier between doctor and patient through national health insurance would bring an enormous increase in demands upon doctors and consequent deterioration of their service. The experience of voluntary plans in this country has been to the contrary. Malingerers are vexatious but few. Most people do not want to be doctored or hospitalized unless they have to be. The current British experience with the new National Health Service also is enlightening Since the service began last July, there has been a huge demand for dental care, eyeglasses and some other benefits for which there was a vast backlog of unmet need But the demand for the services of general physicians has increased only four per cent.

The national health insurance bill does not promise to deliver "complete and adequate medical care" to everyone everywhere in the U.S. But it goes to the heart of both the immediate and the long-range problems. 1) making modern medical care financially available on a democratic basis; 2) providing professional and economic incentives for the increase of high-grade personnel and facilities and their distribution according to need; and 3) placing the people who receive and pay for service in sound relations with the professions and institutions that serve them.

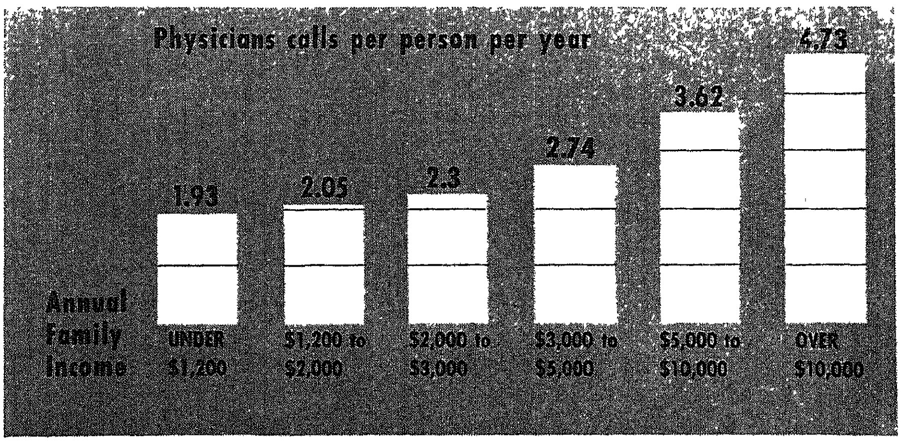
We are now in the midst of a widespread campaign and debate over medical care on a scale never matched in any other country, with powerful forces on both sides. Emotional issues of sickness and health, professional habits and popular desires are intermingled with technical questions of services, organization and finance. The issues mean much to democracy and security in America. Thoughtful men within the medical profession and outside it must keep cool minds to weigh them.

Michael M. Davis is chairman of the Committee on Research in Medical Economics.

SERVICES

Type of plan	N.H.I.B.	BLUE CROSS	BLUE SHIELD	GROUP PLANS	COMM'L INSURANCE PLANS
Physician's care in home and office	√			√	PARTIAL
Physician's care in hospital	√			√	PARTIAL
Surgical care	√		√	√	PARTIAL
Hospital care	√	PARTIAL		√	PARTIAL
Maternity care	√		PARTIAL	PARTIAL	PARTIAL
Preventive and Routine diagnosis	√	PARTIAL		√	
Dental care	√			PARTIAL	
Home nursing	√				
Drugs	PARTIAL				
Eyeglasses and Appliances	√				
Number of Members	100 Million	33 Million	10 Million	3 to 3½ Million	21 Million

MEDICAL COVERAGE of present and future insurance plans varies widely. Group plans are presently the best. Plan proposed by the national health insurance bill is even better. Blue Cross presently has the greatest number of members. Potential membership of national insurance plan is 100 million.



INCOME LEVEL influences medical care, a fact which national health insurance would do much to eliminate. Figures are from the five-year study made by the Committee on the Costs of Medical Care between 1927 and 1932. Relative medical care at various income levels has changed little since then.

THE BLISTER HYPOTHESIS

Huge pockets of hot rock below the earth's surface may account for many of its features. A geologist reviews his theory, notably in regard to mountains

by C. W. Wolfe

A CONSIDERABLE part of geology is based on information supplied by rocks in mountainous regions. These masses of rock are thrust up from ordinarily inaccessible depths to places where they may be observed. Erosion and other processes have then laid bare rocks formed in the geologic past, which tell us much about the history of the earth. For all the work that is based on mountains, however, there is little that explains the origin of mountains themselves. This article presents a new theory of mountain-building developed by the author.

The basis of the author's theory is that the initial forces of mountain-building are supplied by heat that is trapped in pockets within the earth's crust and the region immediately below it. These pockets become huge "blisters" of expanding rock which push upward and raise the overlying material. The blister hypothesis, in the author's opinion, accounts for many things we know about mountains of the geologic past and present. It will not tell us everything about mountains, but it will bring fresh insight to the problem.

One could avoid difficulties and assume that the hills are "eternal," that they were created by some sudden catastrophe and have changed but little since. This simple and, to some people, satisfying picture is completely unsatisfactory so far as the geologist is concerned. Every day the Mississippi River dumps a visible load of material into the Gulf of Mexico; the amount of soil and sand it collects on its way to the sea is enough to lower the entire surface of North America about one inch every thousand years. Much of this material is obtained from the highland regions of the Appalachians and the Rockies, which are presumably being worn down at a much more rapid rate.

These facts cannot be reconciled with the notion that existing mountains were created at the beginning of geologic time. The evidence indicates that the earth is at least two billion years old, and it would be necessary to assume that the original masses were impossibly high to explain their present dimensions on the basis of erosion and other effects operating throughout the earth's history The only alternative is that mountains have grown and decayed and grown again since the earth was young.

The evidence is compelling that mountain-building proceeds in cycles. The pattern begins with a period of quiescence in a limited region of the earth. This phase marks the birth of a geosyncline, a huge trough which gradually sinks under the weight of sediments that are poured into it The sinking prepares the way for the occasional intrusion into the sediments of liquid rock from below the earth's crust. During this phase the seas rise and much of the land is flooded. At intervals there are minor reversals of movement: the waters recede as the sediments of the geosyncline are locally compressed and folded.

The second stage of the mountain-building cycle is "revolution," a complete reversal of the conditions of quiescence. The sediments are folded extensively, the waters retreat on a larger scale, the mountains begin to rise Extremely varied climates also appear, because land masses and mountains interfere with the movement of winds. A simple folding of the rocks, however, is not enough to account for the great heights of today's mountain ranges. It is the third stage of our cycle that is responsible for the lofty peaks of the Himalayas, the Alps and the other mountain chains.

The folding pushes deep extensions or roots into the weak subcrustal region. Since such a root is considerably lighter than the plastic medium in which it floats, it tends to rise buoyantly, producing uplifts of thousands of feet. When the mass reaches a point where it no longer rises or falls, it is said to have attained a state of isostasy, or floating equilibrium. This completes the "creative" part of the mountain-building cycle. Erosion then regains the upper hand and begins to grind the region down to sea level. The cycle is completed, only to begin again in other places, or perhaps in the same general region.

The blister hypothesis, or any other theory of mountain formation, must account for such cycles, but it must also account for a good deal more. For one thing, it must provide insight into certain puzzling problems of geographical distribution. A relief map of the earth clearly emphasizes the fact that mountains are confined to restricted areas Regions elevated more than 3,000 feet above sea level, in fact, are exceedingly rare. An almost continuous belt of mountains circles the Pacific from Antarctica north through South America, North America, the Aleutians, and south through Japan, the Philippines and New Zealand Volcanoes and earthquakes are common occurrences in this belt of youthful mountains. A second imposing belt starts in the East Indies, swings northwest in a wide arc and ties in with the great east-west Himalayas-Caucasus-Alpine system. Volcanoes are rarer in the latter mountains, but earthquakes occur with impressive frequency and violence.

Another great mountain region, the mid-Atlantic Ridge, lies beneath the ocean and is one of the world's longest and highest ranges. Here and there a few islands loom out of the Atlantic to bear witness to the submerged system The Hawaiian Islands are the top of a great chain of volcanic peaks rising as much as six miles above the ocean floor, and other Pacific islands have similar origins Rocks in Brazil, Canada, Finland and other countries furnish evidence of ancient mountain belts that have been so eroded that only their roots are left.

Any successful theory must also explain the kinds of mountains. Erosional mountains are those which great rivers carve out of plateaulike regions, the Appalachians being a good example. It should be pointed out that all peaks except volcanoes are the indirect result of erosion. No mountain-building process is so rapid that its effects are not appreciably modified by the action of streams or glaciers.

A second type of mountain—the domal—would not be conspicuous were it not for erosion. The Black Hills of South Dakota arose from a dome of ancient granite that was lifted several thousand feet along with its cover of younger sediments. The great granite core of Mount Harney standing in the central portion of the Black Hills was

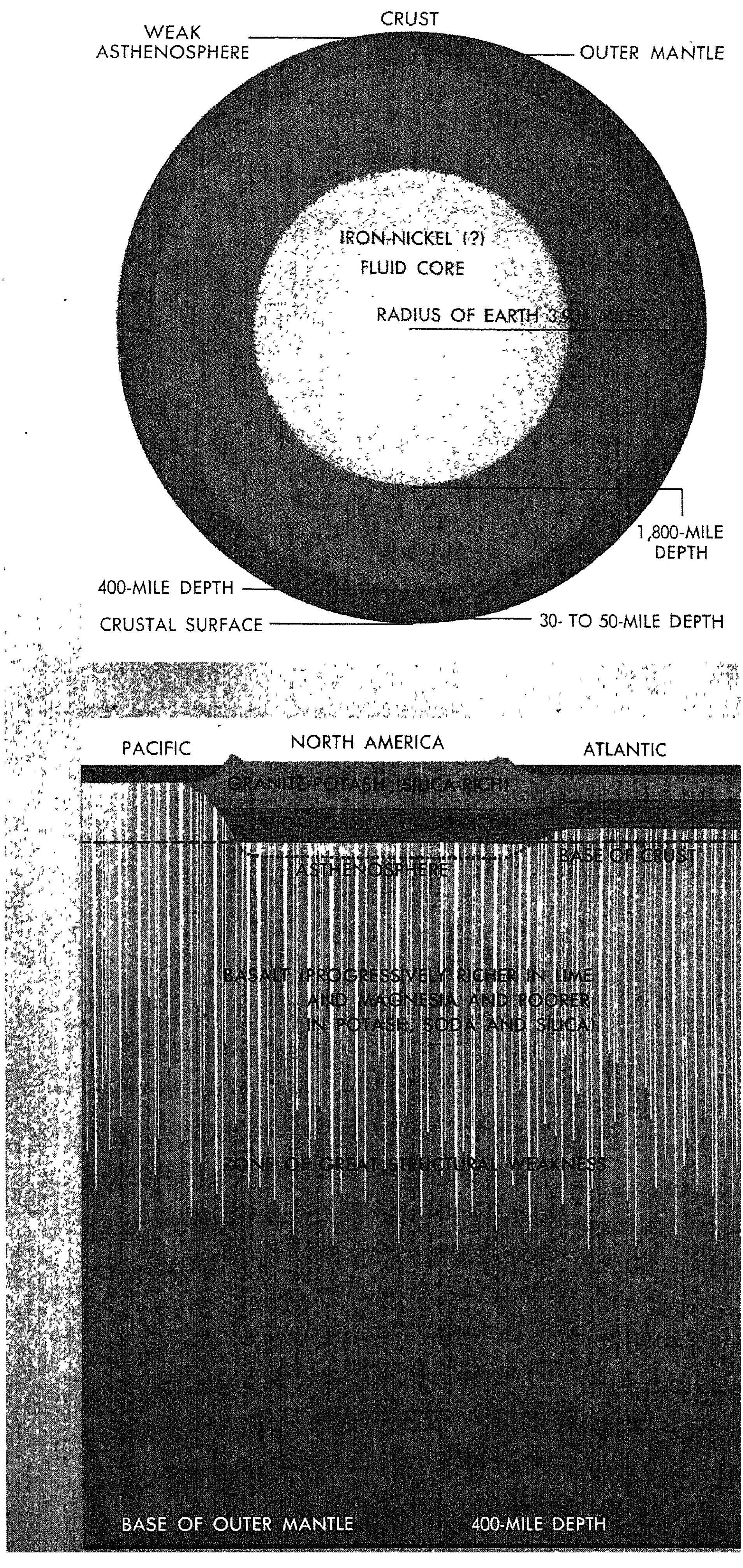
exposed and sculptured by the waters of many streams.

Mountains known as fault blocks are formed when the earth's surface cracks and masses of rock slip against one another along the line of fracture. The rise and fall of such masses produced many of the isolated ranges of the southwestern U.S. The eastern front of the Sierra Nevada was built by perhaps thousands of small movements along the same fault line.

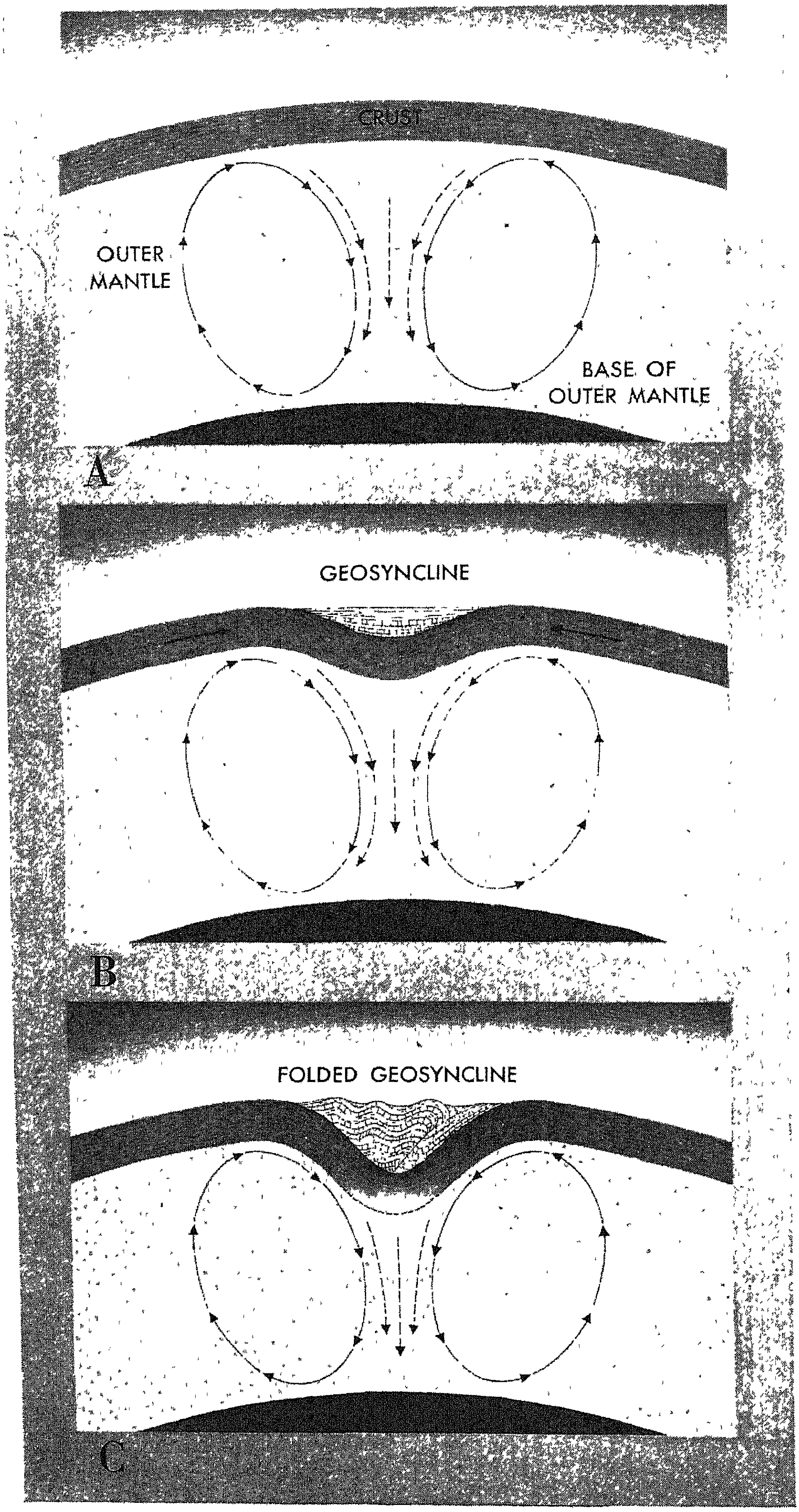
Finally there is the compressional mountain, a type which has presented the geologist with more questions than any other. Certain sections of the crust have been squeezed mightily together. The more brittle surface rocks splinter and override others, while the more easily deformed rocks in the deeper crust are highly warped and folded. Such compression involves a real shortening of the earth's circumference, at least in a restricted region, although the actual extent of the shortening may be a controversial matter. Some geologists believe that the formation of the Alps involved a shortening of 500 to 1,000 miles, and a similar or larger figure has been suggested for the Himalayas.

HOW do some representative theories of mountain-building shape up when examined in the light of what we have outlined? How well do they account for what is known about newer rocks solidified from the molten state, cycles of uplift and erosion, geographical distribution, apparent shortening of the crust and other phenomena? According to the classical contraction theory of Charles Darwin, an originally hot and fluid earth gradually cooled until it formed a definite crust and solidified deep toward the center. As the cooling proceeded the interior shrank But the crust, having already solidified, could adjust to this contraction only by a wrinkling of the surface, such as takes place in the skin of an apple when the interior is dehydrated The earth's wrinkles are mountains. One of the chief objections to this hypothesis is that, if it is true, mountain-building should be going on all the time and practically in all places at once; it is a spasmodic process restricted to definite regions. And if the apparent shortening of the crust in the Alps is real, a complete solidification of the earth could not produce enough wrinkling to explain it.

Another hypothesis conceives of the continents as vast masses drifting like ice floes across the surface of the earth. Alfred Wegener, the German meteorologist who formulated this continental drift



STRUCTURE of the earth is the framework of the blister hypothesis. Blisters occur within the crust and outer mantle. Vertical scale in drawing at bottom is exaggerated 20 times.



CONVECTION HYPOTHESIS accounts for the growth of mountains on the basis that there are great elliptical currents of plastic material within the earth. When two such ellipses meet, the crust above them buckles downward. The resulting depression is filled with sediments which are folded upward.

theory in 1924, believed that mountains are a direct result of such movements, the Alps were supposedly formed when Africa floated northward and crumpled an ancient Mediterranean geosyncline Proponents of the theory point out that the eastern and western shores of the Atlantic can be made to fit like the pieces of a jigsaw puzzle, and they cite a similar matching of fossil and glacial records along the opposite coastlines. Detailed studies of continental movements do not support the hypothesis, which also shares a weakness of the contraction theory in that it does not account for the geographical distribution of mountains or the cycles of their formation.

A more widely accepted theory postulates that deep within the earth are tides or currents of hot, plastic material, moving in great elliptical paths. In those regions where two of these ellipses meet the overlying crust buckles downward. Sediments that collect in the trough are then folded and pushed upward as mountains. Problems within the theory—such as the difficulty of visualizing systems of sub-crustal currents which could produce the complex contours of existing mountains—are probably greater than the problems that it tries to solve.

THERE is thus a clear-cut need for a new approach that will help account for actual geologic data. The blister hypothesis is presented as a possible answer to many unsolved problems associated with the formation of mountains. It is believed that the phenomena to be described are now actually taking place more than 10 to 15 miles but less than 400 miles below the earth's surface.

In parts of this zone, heat is generated faster than it can be dissipated by conduction or radiation. The source of the heat is assumed to be the nuclear disintegration of radioactive elements, although the consequences of this assumption have not yet been worked out in full detail. As material in the crust, and perhaps in the next shell of structurally weak material known as the asthenosphere, undergoes a marked increase in temperature, its physical state is changed. Crystalline materials first become glassy and amorphous and are then transformed to an almost molten condition. The blister is a pocket of material in such a condition. Since the heated substances may expand 10 per cent or more, a region initially 60 miles thick would increase its radius by at least six miles. The direction of increase would be predominantly upward.

The process begins with the formation of several small "pocket" blisters which extend laterally and in depth until they coalesce to form a major blister. Such large masses of expanding material could vary considerably in size but, for the purpose of this discussion, we shall assume that their minimum horizontal ex-

tent is on the order of 300 miles; the maximum diameter could well be thousands of miles, perhaps even of continental or oceanic proportions. The blister would probably have the shape of a thick, upwardly convex lens.

Since surface rocks are relatively weak when exposed to tensile forces and since such forces develop in the crust directly above the thickest part of the blister, the surface is distorted upward to form a slight dome. Zones of weakness and fractures develop in the dome, and molten rock is forced out of the blister by the pressure of the surrounding crust on the underlying plastic materials. Any loss of heat resulting from the release of molten rock necessarily produces a cooling and partial collapse of the blister. Volcanic action is not likely to cause complete collapse, however, because the fractures are readily sealed as the liquid solidifies.

As long as heat is generated faster than it is lost by conduction, radiation and volcanism, the blister will continue to expand laterally. This tendency to creep sideways is accelerated by the weight of the crust above the blister. As the plastic mass deepens and spreads, the radius of the earth in the region is increased by an amount equivalent to the thickening of the blister. We have already indicated that the surface might well be raised six miles, and a much greater increase is entirely within the bounds of possibility.

We have described the forming of a great dome above the center of the blister, but what happens at the surface above one of the edges of the slowly spreading mass? The tensions here cause a yielding of the crust and probably a pronounced thinning of the underlying asthenosphere. The weakened surface sinks to form a trough for the possible accumulation of sediments; such a geosyncline might develop on only one side of the blister or surround it completely. In any case, the crust is thinner below the geosyncline and, as the blister continues to expand, subcrustal materials rise closer and closer to the surface. The release of pressure could liquefy some of these materials with little if any added heat, and the molten rock would be forced into the overlying geosyncline and into any sediments that might be accumulating there. The molten material solidifies rapidly and its added weight causes the geosynclinal region to sink until it reaches a state of equilibrium. This process of doming, geosyncline formation and release of molten rock repeats itself as long as the blister remains.

Now that we have described some preliminary details of the blister hypothesis, we can correlate its hypothetical steps with events that are known to have occurred. As has already been pointed out, the first stage of the mountain-building cycle includes occasional volcanoes, which may result when a blister forms. Cracks opening above the blister furnish vents for the escape of molten rock. The volcanic material ejected from below a continent will generally consist of diorite, a coarse-grained rock which, together with granite, underlies most of the earth's surface. Molten rock ejected from beneath the Pacific Ocean, however, will be rich in calcium and magnesium, for reasons to be discussed, there is no diorite or granite layer under this ocean.

THE first stage of mountain-building is also characterized by a flooding of the land and other accelerating disturbances which can be accounted for by the blister hypothesis. A blister forming beneath an ocean, of course, will raise the bottom and flood the lowlands. Any subsequent cracking and ejection of molten rock will release heat from the blister and cause it to shrink, as a result the ocean floor will sink again and the waters will recede. A shrinking of the blister in the direction of the earth's radius will necessarily produce a shortening of the circumference, but the crust cannot return to its original contours. It contains new masses of solidified rock. The trough regions have also been stretched by the creeping underground plastic mass and have possibly filled with sediment. In attempting to return to the previous circumference, the crust will crumple here and there in the weakest zone, the geosyncline. A disturbance occurring early in the cycle may therefore be interpreted as a partial collapse of a developing blister with some mountain formation and volcanism in one section of the encircling weakened zone.

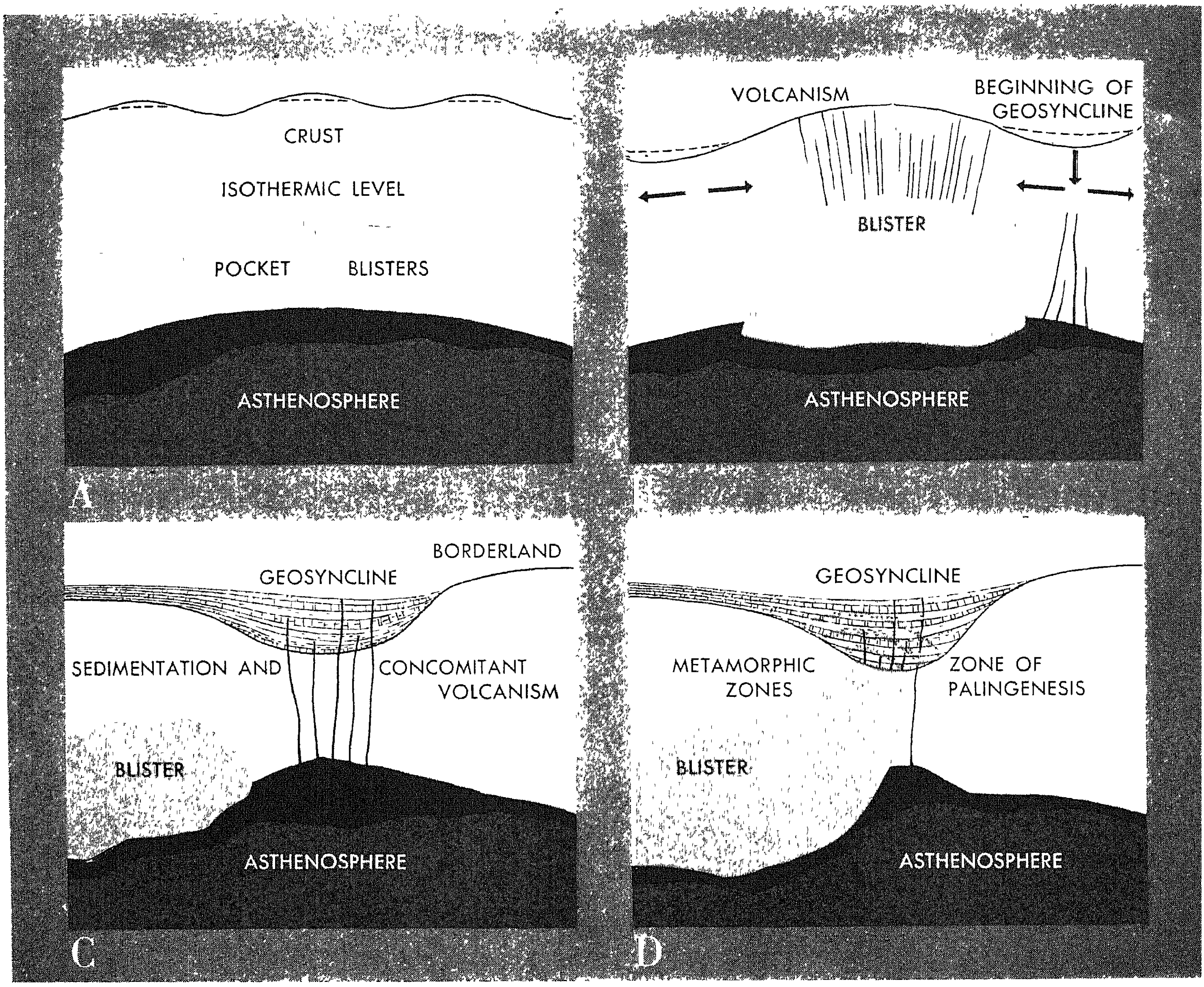
Revolution, the second stage of the cycle, is also explainable in terms of our hypothesis. Several disturbances may occur periodically in widely separated areas surrounding the blister, but these are not sufficient to release all of the accumulating heat. The blister continues to spread horizontally with minor reversals until its edge reaches the sagging geosynclinal zone, the weakest portion of the crust. The heat of the approaching blister raises the temperature of vast quantities of connate or trapped water in the sediments several hundred degrees. This creates a vast crucible in which rocks metamorphose, *i.e.*, change their form and crystal structure. Soft sedimentary rocks become hard, limestone turns to marble; sandstone becomes quartzite; impure sediments are transformed into schist. The stage is set for a full-scale episode in mountain-building. The hot, trapped waters serve as a sort of lubricating agent, while the active force is the pull of gravity on the roof of the blister which overlies a highly plastic or liquid zone. The roof's downward movement results in a lateral thrust at the margins, and crumpling begins. The collapse of the roof is produced not only by simple contraction of the blister materials, but also by the tremendous loss of molten rock which escapes into and through the sediments of the geosyncline.

So according to the blister hypothesis, folding of the crust may be caused by two distinct processes. The initial force is the lateral thrust of the enlarged blister roof as it shrinks to a smaller circumference. The second force is the result of the intrusion of vast quantities of molten rock into the sediments of the geosyncline. The apparent shortening of the crust observed in some zones of mountain-building is partially explained by the stretching and flow of metamorphosed rocks, and by the forcing of molten material into the blister roof and geosyncline.

Great mountain elevations, however, are not produced by simple blister collapse. They result from the fact that during the crumpling of the geosyncline great masses of rock are thrust like roots into the plastic asthenosphere, the layer that lies immediately beneath the outermost crust and extends to a depth of 400 miles. Although these roots flatten out and disappear in time, they tend to float upward through denser materials and set up tremendous buoyant forces which lift the folded sediments to considerable heights. Each elevation is accomplished only when the buoyancy exceeds the strength of the rock, and the lifting action produces tension. This explains one form of fault-block mountain.

Eventually equilibrium is established, and a thickened, eroded continental segment will remain to indicate the former activity of the blister. Succeeding blisters may develop in the same place or in different places. Cyclical processes are quite common, and thus the continent may grow by the periodic addition of new thickened portions. The oceans sink deeper and deeper and the continents rise higher and higher as the lighter subcrustal materials beneath the blisters are separated from the heavier and are brought to the surface with each revolution.

It should be pointed out that the blister hypothesis provides no immediately apparent explanation for the fact that part of the earth's surface is composed of a silica-rich granite and part—notably the floor of the Pacific Ocean—of a silica-poor basalt. It is assumed that a granitic layer was originally distributed over the entire surface, and that part of it was torn away when the moon was formed. According to the British astronomer George Darwin's theory, this event took place when the rotation and vibration periods of the earth were such as to make the earth an unstable body which gradually assumed the shape of a pear, the narrower part eventually breaking away



HISTORY OF A BLISTER might begin with the formation of pocket blisters in a region where heat accumulates more quickly than it is dissipated (A). These coalesce to form a larger blister which pushes up the overlying crust (B). Sediments collect in the geosyncline around this region (C). As the blister continues to ex-

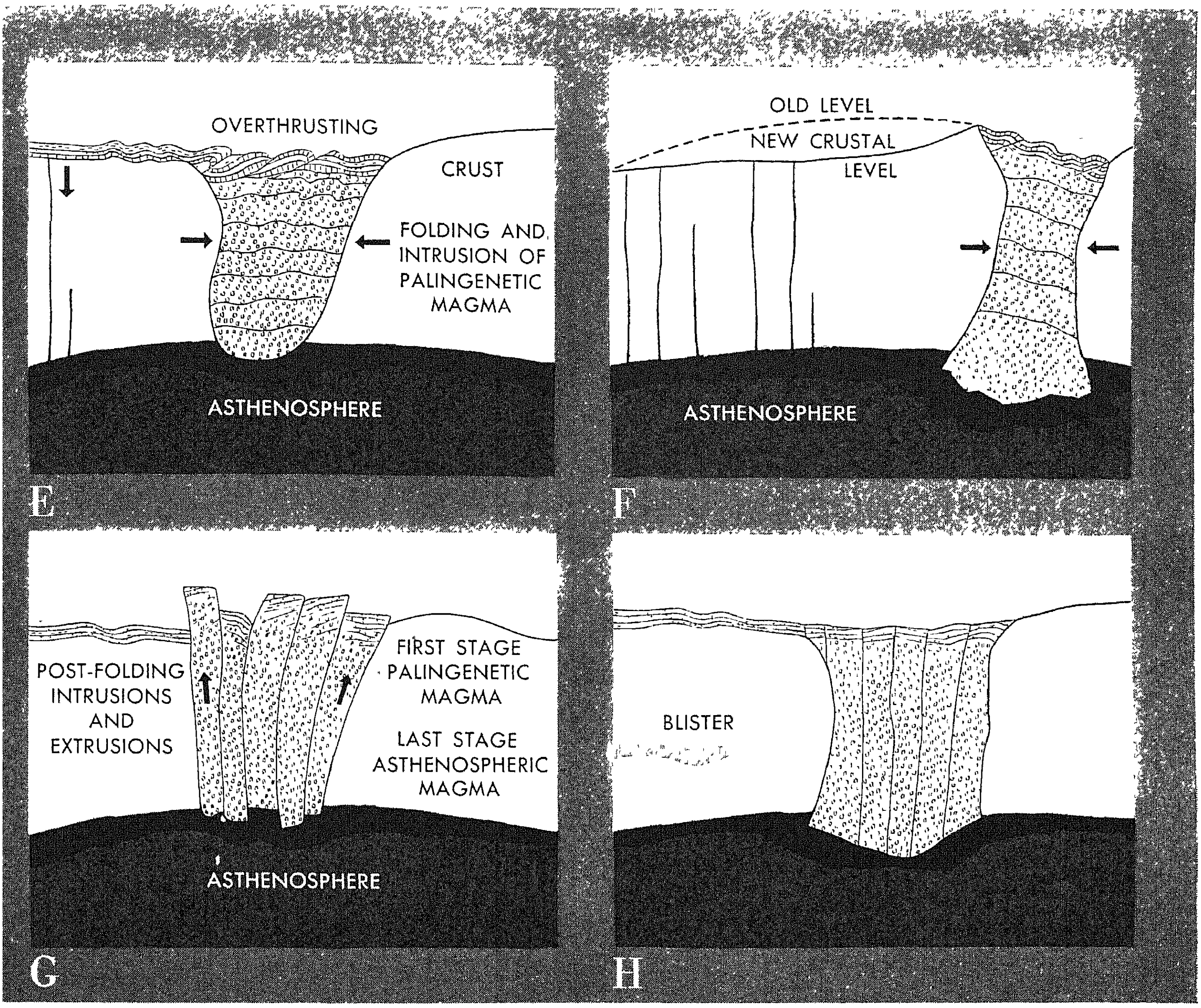
to form the moon. Supporting this view is the observation that the moon is slowly retreating from the earth. By following this process backward in time, it appears that the moon must have been formed after the earth.

A simple calculation shows that if the moon were derived from an area the size of the present Pacific Basin, it would have drawn materials from a depth of 80 miles. That means that the moon would be basaltic, and its mean density is entirely consistent with the calculated depth of removed material and its assumed composition. The rocks of the Pacific floor are denser than those of other portions of the crust. They also seem to be much richer in calcium and magnesium, and poorer in iron, sodium, potassium and silica. The Pacific, furthermore, is exceptionally deep. Such unique conditions are best explained by George Darwin's theory. Since a universal ocean is assumed to have covered a 10-mile-thick universal granite layer before the sloughing off of the moon, sedimentation was practically impossible until the satellite was formed. We have evidence of sedimentation far back into the Archean Era, more than a billion years ago. So the ejection of the moon must have taken place at least that long ago and probably initiated that era.

The sediments themselves offer further evidence that the moon was once much closer to the earth. The widespread, homogeneous sedimentary rocks that were laid down in what is now the central U.S. 225 million to 500 million years ago can be explained by assuming the existence of a vast tidal basin in ancient times. This could have been the case only if the tides were considerably higher, a situation that presupposes a closer proximity of the moon. Tides of 50 to 100 feet are easily imaginable with the moon about 24,000 miles, or one tenth of its present distance, from the earth. The effect upon sedimentation would have been tremendous. Although the origin of the Pacific Basin must remain a matter of conjecture, the above arguments are highly suggestive. It is interesting to note that the blister hypothesis can readily explain most of the surface features of the moon as well as of the earth.

WHAT specific geological events provide the best examples of blister action in the past? A recent paper by the University of Michigan geologist A. J. Eardley furnishes one possible illustration. He has shown that the entire Arctic Ocean region was once dry land which disappeared after a mountain-building revolution at the close of the Paleozoic Era. This revolution produced the folded ranges distributed around the North Pole, and might well have been caused by the collapse of a blister.

Another example may be provided by



pand laterally, it pushes into the sediments (D). Here *the blister loses heat and collapses. The crust above it* likewise collapses, squeezing the sediments of the geosyncline (E). These folded sediments remain as mountains *(F). As they float, they may be fractured into* fault blocks (G). Finally the blocks are eroded flat (H).

an examination of Paleozoic maps, which show a land mass to the east of the U.S. A more or less continuous geosyncline extended from Alabama through Newfoundland, for all we know, it may have reached across to the British Isles, and from there to the region of the Paleozoic Alps. It is possible to imagine a blister and perhaps a continuous land mass occupying the region that is now the Atlantic Ocean. The collapse of such a blister would not have occurred over the entire area at once. Three partial collapses might be represented by the Caledonian revolution of Scotland beginning 300 million years ago, the Acadian revolution of the Canadian maritime provinces beginning 260 million years ago, and the revolution that formed the Appalachians 200 million years ago. After the latter revolution, fault-block mountains and basins formed along the entire folded belt from Connecticut to Virginia. Meanwhile the central portion of the blister might have continued to collapse, forming the Atlantic Basin.

Although one cannot point with great assurance to modern signs of blister activity, a few cases may be discussed. The elevated continent of Africa, with its great "rift valleys" caused by cracks in the crust, may constitute the roof of a blister. The fact that the northern half of the Pacific Ocean is 3,500 feet deeper than the southern half may be accounted for by assuming complete blister collapse in the former region. The islands of Japan are grouped in an obvious mosaic pattern. They could well be masses of the crust that are being raised by the buoyant force of deep fault-block roots resulting from the collapse of such a North Pacific blister. The East Indies possibly represent a similar phenomenon, with the blister center slightly to the northwest of Borneo. The great peaks of the Himalayas could very well be the product of two or more coalescing blisters.

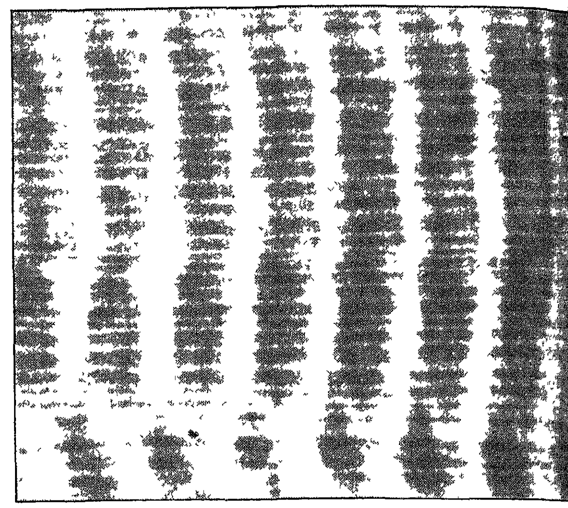
These and other speculations based on the blister hypothesis will undergo thorough examination and testing when the facts of ancient geography are reconsidered in the light of its basic assumptions. The hypothesis will stand or fall depending on detailed quantitative findings concerning the distribution of radioactivity in the crust, the heat-conducting properties of rocks and many other important physical factors. The author is not completely satisfied with the theory as it stands. It is presented because, as far as preliminary considerations go, there seems good reason to expect that some such explanation will prove valid. Time will prove the judge.

C W. Wolfe is professor of geology at Boston University.

MUSCLE RESEARCH

The contractile tissue has many remarkable characteristics. Not the least of them is its usefulness in the investigation of life itself

by A. Szent-Gyorgyi



A MUSCLE FIBER has horizontal and vertical markings in photomicro-

WHEN one of our muscles is excited by a nerve, it contracts. Some muscles are thus able to pull at the bones to which they are attached and to move a part of the body. Other muscles perform much of the work of our internal organs. The heart is only a pouch of muscle, so, in a way, are the intestines. Millions of muscle cells are embedded in the walls of small arteries.

Much of human suffering is due to the disfunction of these inner muscles. A slight contraction of the muscles of the arteries may send the blood pressure up or cut off the supply of oxygen to other tissues. More than half the deaths of mankind are due to the failure of heart muscle. Yet in most cases we cannot repair the diseased muscle machine because we do not sufficiently understand its structure and function.

Muscular contraction is one of the most wonderful phenomena of the biological kingdom. That a soft jelly should suddenly become hard, change its shape and lift a thousand times its own weight, and that it should be able to do so several hundred times a second, is little short of miraculous. Undoubtedly muscle is one of the most remarkable items in nature's curiosity shop. Muscle, however, has attracted the attention of many scientific investigators for another reason.

All living organisms are but leaves on the same tree of life. The various functions of plants and animals and their specialized organs are manifestations of the same living matter. This adapts itself to different jobs and circumstances, but operates on the same basic principles. Muscle contraction is only one of these adaptations. In principle it would not matter whether we studied nerve, kidney or muscle to understand the basic principles of life. In practice, however, it matters a great deal.

The work of the scientist is essentially to measure, and the rapid changes in muscle can be measured much more easily than the slow changes in liver or kidney. The functioning of muscle may be seen by the naked eye, and may be indicated by simple means. The electrical change of nerve, on the other hand, may be observed only with involved and subtle devices. The great motility of muscle demands that it be built of small units, arranged with great regularity and bound together by relatively weak forces This means that we may disentangle and isolate these small units without destroying them, and that they may be studied outside the body.

There are many approaches to the study of muscle. The anatomist delights in its structure, which he tries to preserve. The physiologist enjoys the harmony of its function, and tries to avoid all damage to the tissue in order to study it under physiological conditions. The biochemist, however, willfully destroys the structure. There is a simple reason for the fact that none of these approaches, in itself, can explain muscle.

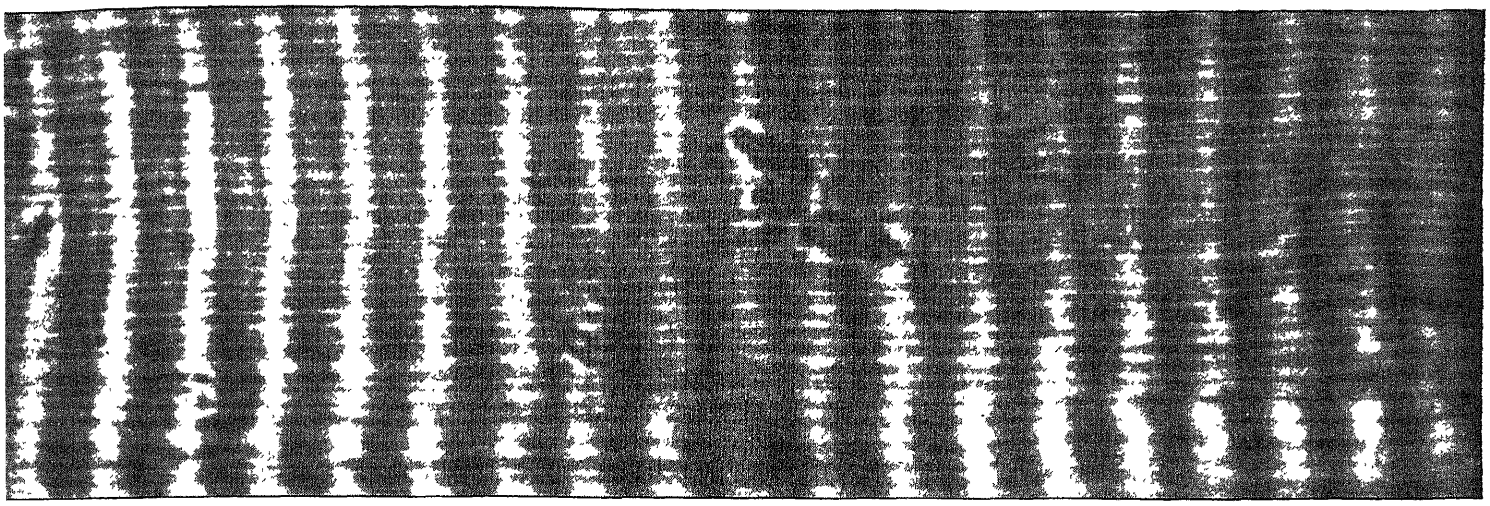
Muscle is a machine, and in any machine we must deal with two elements. One is the energy-yielding reaction, such as the expansion of steam in a steam engine, the burning of fuel in an internal combustion engine, or the flow of current in an electric motor. These elementary reactions can accomplish useful work only if they take place within a specific structure, be it a cylinder and a piston or a coil and a rotor. So in muscle we must also look for both the energy-yielding reaction and the meaningful structure.

The energy-yielding reaction is a chemical change which takes place among molecules, and its study belongs to the realm of biochemistry. The structure is the domain of the anatomist, working with his knife, microscope or electron microscope. Both paths of inquiry are most exciting. We can expect to find that the basic energy-yielding reaction is identical, at least in principle, in all living forms. Muscle research can thus take us to the very foundation of life. Its structure, although specialized, can likewise reveal the fundamental principles of biomolecular architecture. In this light muscle ceases to be a special problem. The study of its function merges with the study of all life, and for such study muscle is a wonderful and unique material.

MUSCLE is built of tiny fibers which are just visible to the naked eye The picture that appears at the top of these two pages shows one of these as it appears under the microscope. If we look at this picture closely, we discover a horizontal striation which indicates that the muscle fiber is only a bundle of many small fibers, or fibrils. These fibrils are composed of contractile matter, and the muscle contracts because they contract. Under the electron microscope, as may be seen in the picture on page 24, the fibril is clearly visible as a slender, continuous column.

The fibrils need a great deal of energy in a very special form. The energy contained in food, in fact, must be converted into this form before the fibrils can use it. This process alone requires a bulky chemical apparatus that is located between the fibrils The contraction of the fibrils presses this substance into disks, which account for the vertical striations visible in the picture above. In the picture on page 24 some of this interfibrillary material still adheres to the surface of the fibril, giving it a segmented appearance. In the picture at the top of page 25 we can see that the substance indeed adheres only to the surface. Where the fibril itself lies naked we can see that it too is a bundle of still finer threads. These threads have been called *filaments* by C. A. Hall, M A. Jacus and F. O. Schmitt, who first photographed them at the Massachusetts Institute of Technology.

The specific form in which energy is supplied to the fibril is adenosine triphosphate, which is abbreviated as



graph. Horizontal striations indicate that fiber is made up of tiny fibrils. Whitish vertical markings show presence of material compressed by fibril contraction. Original photomicrograph magnified fiber 1,000 diameters.

ATP. The discovery of this substance is one of the most important achievements of biochemistry. ATP is one of the main axes about which life revolves. The ATP molecule bears three phosphate groups linked by oxygen atoms. The University of Pennsylvania physiologist O. Meyerhof has shown that the manufacture of each such link requires 11,000 calories of free energy. When the links are broken, the energy is released. Fritz Lipmann of the Massachusetts General Hospital has called them high-energy phosphate links. Their splitting is the source of all muscular energy

The participation of ATP in contraction has one most fascinating aspect. Our experience thus far indicates that wherever there is life its carrier is a nucleoprotein. This substance is made up of protein and nucleic acid, the latter being most abundant in cell nuclei. We may therefore assume that these two materials and their interactions are an essential feature of life. The nucleic acid molecule is composed of many small units that are chemically similar to ATP. These are joined in giant fibrous molecules. Unfortunately we cannot do much with such large molecules, so they can tell us little of the nature and meaning of nucleoproteins.

Again muscle furnishes a hopeful exception. So far as the author is aware, the contractile substance of the fibrils is the only "living" protein that is not linked to nucleic acid. The reason is easy to find. Long, fibrous nucleic acid molecules would surely interfere with the mechanism of contraction. Instead of nucleic acid, the contractile protein works with smaller units. In the author's opinion, ATP is the missing nucleic acid of the fibril. Since ATP is a small molecule, its connection with muscle protein can be studied with relative ease, and may reveal one of life's most closely guarded secrets.

Having outlined some general principles, let us see what we can actually learn about the function of muscle. To understand it we will have to break it down. From a knowledge of its parts we may hope to understand the whole, just as the astronomer understands the stars by his knowledge of the atom. A man who parachuted into a strange land, however, might have difficulty in finding his way home. We would likewise have trouble finding our way back to muscle if we decomposed it all at once. We will fare better if we proceed to our destination on foot, and decompose muscle step by step.

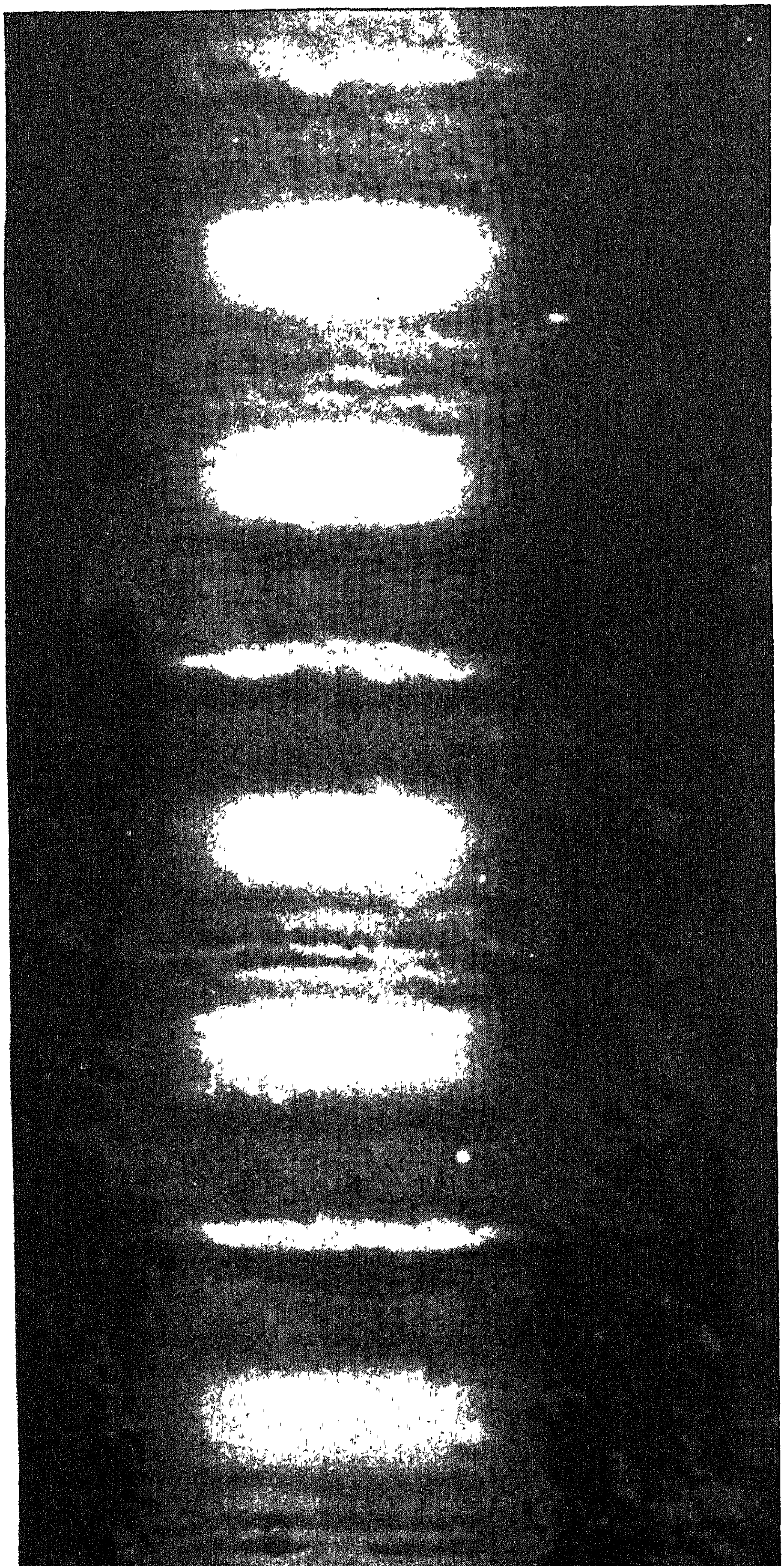
As the first step in decomposing muscle, let us separate the small, soluble molecules from the insoluble structure without destroying the latter. This can easily be done by washing a strip of rabbit muscle, for example, with water. Now let us put the dissolved molecules back again. We suspend our muscle in a concentrate of the original solution, or, to simplify matters, in a boiled extract of some other muscle tissue. What happens? The muscle contracts! Special measurements show that the contraction occurred with such force that the muscle could have lifted a thousand times its own weight, just as any living muscle. There is no doubt that what we have seen is muscle contraction.

Next we ask: What substance in this muscle juice made the washed muscle contract? Fortunately this is not a difficult question. A bit of scientific cookery indicates that two substances were responsible—potassium and ATP. This is remarkable, for ATP is essentially phosphate, and if we want a lawn to flourish, we use a fertilizer containing potassium and phosphate. Grass needs the same substances as muscle, a striking demonstration that the basic change in muscle contraction is only one form of a universal biochemical reaction.

We have thus discovered that ATP makes muscle contract as well as supplying the energy for contraction. No other substance will serve. ATP is a cogwheel in the mechanism of contraction, and without it no contraction occurs. ATP has yet another function. From earliest times man has known of *rigor mortis,* the stiffening of the body that follows death. The same effect can be produced in a single muscle. A strip of rabbit muscle removed soon after killing the animal can be stretched like rubber, though within narrower limits. A few hours later the strip becomes inelastic and simply breaks when we attempt to stretch it. The loss of elasticity is due to the decomposition of ATP; by restoring ATP we restore elasticity If ATP did not make muscle elastic, the muscle would be too rigid to work at all.

We can now go one step further in decomposing muscle. We make a very fine pulp of our washed rabbit muscle, suspend it in water and add potassium and ATP No contraction can occur because the structures have been destroyed. Instead there is a violent precipitation. Much the same thing must have happened when the whole muscle contracted. The precipitation of fine colloidal particles is due chiefly to a loss of electric charge. So the basic reaction of contraction is a loss of charge, brought about by potassium and ATP.

We may now proceed to decompose muscle into its molecules. In the presence of ATP a strong salt solution dissolves the muscle structure and extracts two quite different proteins—actin and myosin. Both of these proteins have most interesting properties, but contractility is not one of them. The most amazing property of myosin is its great affinity with ions, which in the smallest concentrations may greatly modify its electric charge. The most amazing property of actin, discovered by the author's associate F. B. Straub, is that it can exist in two forms. When first extracted it consists of small, round molecules. If we add a little salt these little globules unite to form long threads, as shown in



A MUSCLE FIBRIL is shown in electron micrograph made by G. Rozsa of the National Institute of Health. Ridges of white material adhere to surface of the fibril. Original micrograph magnified fibril 9,500 diameters.

the photograph at the bottom of the opposite page

The most amazing property of actin and myosin, however, is that they can unite to form a complex—actomyosin. It is this complex that has the contractility of muscle. We have reproduced, and thus made it possible to analyze, one of the most mysterious manifestations of life. Seeing actomyosin contract for the first time was the most exciting experience of the author's scientific career.

We have left the problem of the molecular architecture of muscle to the end, because this field of research was opened not long ago when the discovery of the electron microscope extended the limit of human vision down to the world of molecules. Hall, Jacus and Schmitt were the first to begin studies along this line. At present the problem is also being investigated at the National Institute of Health by G. Rozsa, the author and R. W. G. Wyckoff, in the laboratory of the latter. These studies have shown that the building of actin out of globules into fibers proceeds in two steps. First perhaps 20 globules unite into a slightly elongated particle some 300 Angstrom units long and 100 wide. Then these particles are joined end to end to form threads. Electron-microscope photographs show that the threads have a strong tendency to come to rest side by side so that the individual particles of neighboring threads also lie side by side. Thus threads actually form in two directions, and a regular structure analogous to a crystal results.

THE nature of the chemical mechanism that makes large protein molecules out of small ones is a very fascinating problem. The larger actin particles are the size of the smaller viruses. *The question of how* a large protein unit is put together, and how it is taken apart and put together again according to a new pattern, is perhaps the most important problem of virus research. W. J. Bowen and K. Laki of the National Institute of Health have shown that ATP is also involved in this feat of molecular engineering.

There is yet another new and rather hopeful approach to muscle, opened by the discovery that muscular contraction is a so-called equilibrium reaction. The approach is that of thermodynamics. It has thus far yielded two rather fascinating results. It has shown that the whole muscle machine is built of small and more or less independent units the size of actin globules. These have a molecular weight of 70,000, *i.e.*, 70,000 times the weight of the hydrogen atom. If linked to ATP, the units at rest have a certain amount of potential energy, and are thus comparable to a loaded gun or an extended spring. When excited by a nervous impulse, the units spend this energy. The energy transmitted by ATP

is then required to bring them back to the high-energy loaded or extended state. Once we know this, it seems natural that nature should do it this way. The living structure is kept ready to fire and is loaded after firing, instead of the other way around.

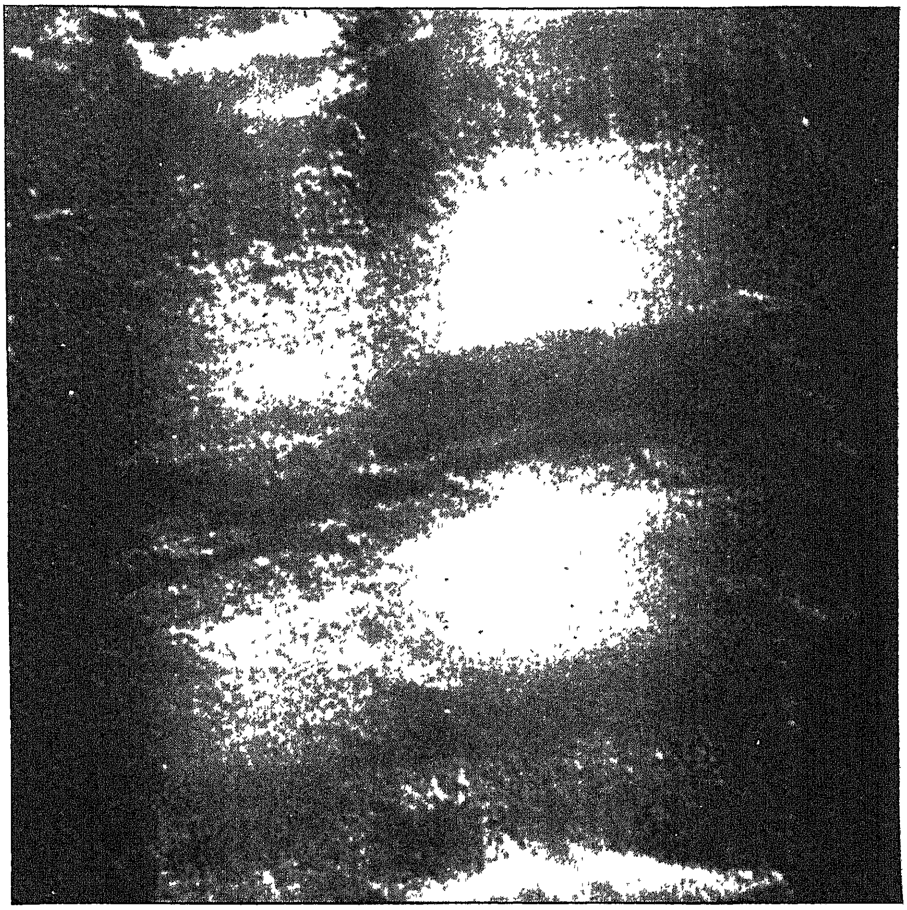
Can we put all this together in a single theory of muscle contraction? We can try, but we must jump some rather wide gaps We have seen that the primary reaction is a change in which electric charge is lost, and that the change takes place within small molecular units Such a loss of charge must very greatly alter the forces between the larger particles. Should it be found that the muscle fibril is a three-dimensional structure of slightly elongated particles, it might also be found that contraction is nothing more than a tilting of them.

Much work must be done before we have a rounded understanding of muscle contraction itself. Then we must ask what changes occur when a nerve commands a muscle to contract, how the system returns to its resting state, and how the energy of ATP is transferred. Since actomyosin appears to be identical in all kinds of muscle, we will have to look out for the substances that regulate its varying functions. In the wing muscle of some insects, for example, actomyosin can contract several hundred times a second, yet it can also produce the slow, regular beat of the heart and, without consuming energy, can hold a clam shell closed for hours.

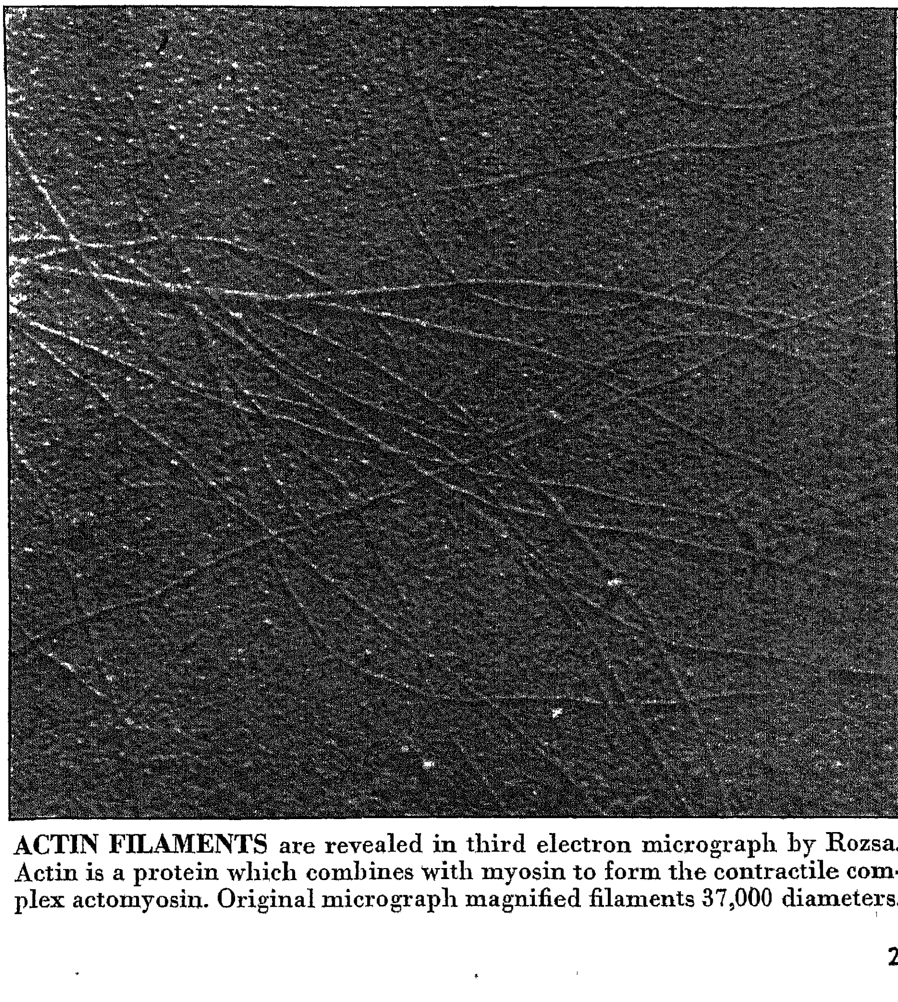
The reader may ask: When we know all this, will we understand muscle and life itself? The author can only give his personal opinion· We will not, because the fundamental changes in muscle cannot be expressed in terms of orthodox chemistry. We will very likely have to explain them in terms of how electrons are distributed over the entire molecular structure, an explanation that belongs to the realm of quantum mechanics.

The study of this distribution of electrons within the protein molecule is one of the most urgent and most difficult tasks of biology. Until the task has been completed, we cannot hope to understand the nature of life The task is not impossible, but it requires keen imagination, a lust for adventure, and a catholic knowledge. The task is probably too big for any one man; the biologist and the theoretical physicist will have to collaborate. A few hopeful beginnings have been made. They may eventually lead us to a full understanding of the protein molecule, which will mark the beginning of a new era in biology and medicine.

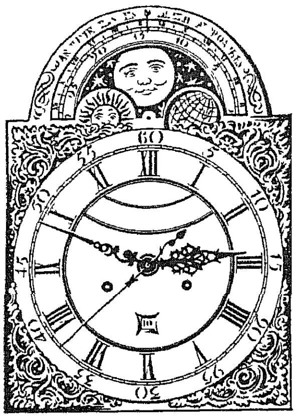
A. Szent-Gyorgyi, Hungarian biochemist and Nobel prize winner, is now a fellow of the National Institute of Health and director of the Institute for Muscle Research at Woods Hole, Mass



FINE STRUCTURE of a fibril is visible in another electron micrograph by Rozsa. Beneath the white interfibrillary material are tiny filaments that make up the fibril. Original micrograph magnified fibril 25,000 diameters.



ACTIN FILAMENTS are revealed in third electron micrograph by Rozsa. Actin is a protein which combines with myosin to form the contractile complex actomyosin. Original micrograph magnified filaments 37,000 diameters.



Progress in Cancer

CANCER research has recently made some definite progress in its slow journey toward the early diagnosis and effective treatment of the disease. One striking development has been announced by George W. Kidder of Amherst College, who, with a team of co-workers, has discovered a clear-cut metabolic difference between cancerous and normal mammalian tissue. The difference lies in the cells' use of guanine, a substance entering into the formation of nucleic acid. Malignant cells require guanine; normal cells do not.

The finding was applied in a significant experiment. A cancerous mouse was fed a diet including pseudoguanine, a metabolically useless compound which resembles guanine so closely that cells take it up as if it were guanine itself. This antimetabolite did not kill the mouse cancer, but it stopped tumor growth. And growth resumed as soon as administration of the drug ceased. Although pseudoguanine may be toxic to normal as well as malignant cells, the technique represents an approach that may yield results in the future.

Another approach to the problem of curbing the growth of malignant tumors is reported by Henry K. Wachtel of Fordham University in *Nature,* the British scientific weekly. Wachtel has extracted a fatty substance from fresh cattle pituitary glands which inhibits the growth of soft-tissue cancers in experimental animals. In some cases the cancer regressed partly or completely. The pituitary substance also produces a definite effect in the blood, reducing the level of the fatlike compound cholesterol. The identification of the substance awaits its preparation in large quantities.

Three significant advances have also been made in the diagnosis of cancer. S. A. Gladstone of the New York Polyclinic Hospital has developed a simple sponge technique for recovering specimen cells from various body surfaces and cavities. The sponge, which is made of gelatin, is rubbed over areas from which specimens are desired. Enough cells adhere to the gelatin to provide material for microscopic study. The technique is being tested by hospitals in several cities and has been employed in more than 700 cases, including cancers of the cervix, uterus, rectum, mouth, pharynx, esophagus and lung. It is said to be at least as reliable as biopsy, the surgical removal of a tissue sample which is a standard practice in diagnosing cancer. The sponge method may also aid in the diagnosis of gastric cancer, the most difficult form of cancer to detect. The gelatin can readily be inserted into the stomach through a tube.

Another test, for the examination of patients who may have cancer of the cervix or uterus, has been devised by Harold S. Burr of Yale University and Louis Langman of New York's Bellevue Hospital. It is based on the electrical characteristics of living tissue. Contacts placed on the abdomen and in the vagina pick up a negative potential in nonpregnant women with no uterine or cervical pathology. A positive potential is observed in pregnant women and those with cancer or certain other disorders of the genital tract. Erroneous diagnoses were made in only 15 per cent of the tests.

Charles Huggins of the University of Chicago has reported a test for cancer that involves the analysis of blood. Iodoacetic acid inhibits the coagulation of proteins in heated blood serum, and it takes less iodoacetic acid to inhibit coagulation in the serum of a person with cancer. This difference is the basis of the test. Although false positive reactions are obtained in pulmonary tuberculosis and acute infections, these conditions may be easily distinguished from cancer. The test, which provides no information as to the site of the growth, has been checked on 300 persons. Huggins has described it as "not quite as good as the Wassermann test" for syphilis. Blood tests for cancer have been reported on four previous occasions, but until now have proved unreliable.

The New Commissioners

A CONTINUATION of the present policies of the Atomic Energy Commission appears likely from the President's choices to fill two Commission vacancies. Taking the place of Robert F. Bacher, who resigned to go to the California Institute of Technology, is another physicist, H. D. Smyth of Princeton, author of the celebrated official report on the atomic bomb. Gordon Dean, named to the position vacated by W. W. Waymack, is a professor of law at the University of Southern California who was in the Justice Department throughout the Roosevelt administration. Subject to Senate confirmation, Smyth and Dean will serve terms expiring in June, 1950.

The Nuclear Rocket

THE first rocket propelled by atomic energy will not be successfully launched for at least several decades, according to H. S. Seifert, chief of the applied physics section of the California Institute of Technology Jet Propulsion Laboratory. The nuclear rocket, Seifert says in *Physics Today,* "seems to be one of the less practical applications of nuclear energy." It raises more problems than it solves.

The first problem is that a practical rocket must operate at a minimum of 5,000 degrees C. (Below that temperature the velocity of the jet is too low.) Uranium, however, melts at 3,400 degrees. Theoretically a nuclear rocket might work in either of two ways. The simpler is to employ a nuclear reactor to heat the working-fluid—the gas to be expelled—in much the same way that reactors will heat the turbine-spinning gases in the first atomic-power plants. Seifert points out that the best possible rocket working-fluid, liquid hydrogen, heated to the highest practicable temperature, would furnish only four times as much thrust as a good chemical fuel. Very large, heavy tanks would be required to handle this fluid because of its low boiling point and low density.

The other theoretical possibility is the "photon" rocket. Matter would be converted entirely to radiant energy, which would act as a kind of electromagnetic jet, a quarter of a pound of matter providing enough energy to propel a projectile 18,000 miles a second. The Caltech physicist considers the photon rocket as having "no more status at the moment than that of a mere wishful hypothesis." In fact, he finds the immediate prospect for any practical atomic rocket "melancholy."

Soviet Mesons

TWO Soviet physicists claim to have found no less than 16 types of subatomic particles in cosmic-ray debris. In work done more than a year ago, but only now reported outside the U.S.S.R., A. I. Alichanian and A. I. Alichanov declare they have obtained photographic tracks of particles with the following masses (mass of the electron=1): 110, 140, 200, 250, 300, 350, 450, 550, 680, 850, 1,000, 1,300, 2,500, 3,900, 8,000 and about 25,000. The photographs were made at a high-altitude cosmic-ray

CITIZEN

research station in the Caucasus. Alichanian and Alichanov—who are brothers, although one of them has Russianized his name—report their studies in a letter to the British weekly *Nature*.

American and western European physicists have accepted as established the existence of only two similar particles, mesons of mass 215 and 284. These are knocked out of atomic nuclei by either cosmic rays or high-energy radiation from the most powerful atom-smashers. A third meson has never actually been detected, but is generally credited on theoretical grounds. A fourth meson, with a mass of 800 to 1,000, is also accepted by some western physicists.

Syphilis Antibodies

FURTHER details of how resistance to syphilis develops may result from a new technique for detecting syphilis antibodies in the bloodstream. Developed by R. A. Nelson, Jr., and Manfred M. Mayer of Johns Hopkins University, the technique involves bringing together a sample of possibly infected blood and a specimen of live parasites. The presence of antibody and infection is indicated by immobilization of the parasites. The procedure not only permits precise determination of how much antibody is present but may lead to better methods for detecting syphilis. Although it is too laborious in its present form for routine tests, its early use in doubtful diagnoses is anticipated.

Spinal Cord Culture

TWO University of Chicago physiologists, Ralph W. Gerard and Robert T. Tschirgi, have succeeded in keeping a large section of a rat's spinal cord alive and functioning outside the animal's body. The section is an inch and a half long and runs from the base of the skull to the middle of the back. Placed in a trough after dissection from the rat, it is supplied with blood or an artificial nutrient through the spinal-cord arteries. Electrical stimulation of the cord's sensory nerve roots produces a response that may be indicated on a cathode-ray oscilloscope.

Culture of the spinal cord will greatly simplify the investigation of nerve metabolism. Gerard and Tschirgi have already found five distinct substances capable of furnishing energy for nerve. (Glucose had previously been considered the only energy source.) They have also been able to demonstrate that spinal-cord function—in apparent contrast to accepted theories of brain func-

tion—can be restored after as much as 30 minutes of oxygen or glucose deprivation The Gerard-Tschirgi technique may also open the way for the study *in vitro* of multiple sclerosis, poliomyelitis, convulsions and other disorders of the central nervous system.

World Health Assembly

ESTABLISHMENT of six "health demonstration areas" to show the operation of a coordinated, fully developed public health program will be discussed at the second assembly of the World Health Organization, which opens in Rome on June 13 and will continue for several weeks. Nearly 400 delegates and observers representing 59 nations will attend the sessions. Only three members will be absent. White Russia, the Ukraine and the rest of the U.S.S.R. withdrew from WHO in February and consider themselves out of the organization, although the WHO charter has no provisions for the withdrawal of members. The Assembly may refuse to accept their resignations.

The health demonstration areas will be one of the main features of WHO's 1950 program. Each will cover an area with a mixed urban and rural population of 100,000, in a country where some teaching and public health facilities already exist, so that training can be given to personnel from neighboring nations and the work initiated by the demonstration unit can be continued after it leaves. The areas will be in different regions of the world and will be chosen to reflect special regional problems. The list will include several regions where improved public health can be expected to result in a rapid rise in food production.

In addition, WHO plans to send out more medical demonstration teams to spread the campaign against tuberculosis, malaria, venereal disease and the other disorders listed by the First World Health Assembly as WHO's initial areas of concentration. The first steps of a broad campaign against the parasitic infection schistosomiasis will also be undertaken.

The 1950 program will increase the agency's budget from the present $5 million to $17 million. The American share will come to about $6.5 million, and although U.S. delegates are expected to agree to the assessment, a special act of Congress will be needed to authorize payment. Congress last year voted to limit American WHO contributions to $1 9 million a year.

German Chemical Industry

ABOUT two fifths of the great West German chemical industry is to be preserved, according to an agreement among France, Great Britain and the U.S. The decision was based on a survey of the German chemical, steel, mechanical and nonferrous-metal industries by the Industrial Advisory Committee of the Economic Cooperation Administration. A total of 381 plants was studied, of which 144 are to be retained in whole and 15 in part. Of the 75 chemical plants studied, 32 will remain.

Hardest hit is I. G Farben, which will lose 27 of 50 plants, including 17 of the 30 factories in the famous group at Ludwigshafen-Oppau on the Rhine The plants Farben is to retain, however, are nearly three quarters of the total number of chemical establishments permitted West Germany. Unless the combine should be broken up, I. G. Farben will still be the strongest element of the German chemical industry.

The Anglo-French-American agreement also sets production ceilings The manufacture of a long list of chemicals, including *synthetic liquid fuels*, is prohibited outright. Only one synthetic liquid-fuel plant at Wesseling in the British zone will be permitted to operate, and that will be confined to the hydrogenation of otherwise useless heavy crude-oil residues Production of styrene, a basic synthetic rubber intermediate, will be limited to 20,000 tons a year. Surplus plants will be distributed among the Allied powers as reparations. Since most of those earmarked for this purpose have already been dismantled, the reduction of the German chemical industry is nearly complete.

Arctic Iron Age

A LARGE steel mill is being built in the town of Mo, in Norway within 25 miles of the Arctic Circle. Norway's first modern iron and steel plant will turn out 500,000 tons of rolling steel and 180,000 tons of pig iron annually and will be the largest industrial enterprise in the country. Owned by the government, the plant will be completed in 1951.

Because of Norway's lack of coal, the plant will smelt iron ore in electric furnaces, which use only the comparatively small amount of coal needed to react with the ore. Heat for the process is supplied by electricity from a nearby hydroelectric station. The plant will use a specially processed low-grade ore from Dunderland, a few miles away. The world's best iron ore comes from the famous deposit at Kiruna, Sweden, which is not far from Mo, but there is no direct transportation between the two localities

Honors

THE National Academy of Sciences and the American Philosophical Society have chosen 37 U.S. and eight foreign scientists for membership. Among those selected by the Academy at its annual spring membership election were Paul R. Burkholder of Yale, the

co-discoverer of chloromycetin, Kenneth S. Pitzer, research director of the Atomic Energy Commission, and John L Savage who, as chief designer of the Bureau of Reclamation, has designed more large dams than any other man in history. P. A. M. Dirac, the Cambridge University mathematical physicist, and Hideki Yukawa, the Japanese physicist who forecast the discovery of the meson and is currently a visiting professor at Columbia University, were named foreign associates. Altogether the Academy voted in 30 new American and seven foreign members.

The American Philosophical Society, which includes representatives of the arts and letters as well as sciences, elected several new scientific members. These include Saunders MacLane, University of Chicago mathematician, the only person elected to both the Academy and the Philosophical Society, E. U. Condon, director of the National Bureau of Standards; and Max von Laue, the German physicist.

Foundations

AT least 899 private foundations are operating in the U.S , according to the most complete survey yet made. The survey, prepared by Wilma S. Rich and Neva R. Deardorff of the Raymond Rich Associates, is published under the title *American Foundations and Their Fields*.

Most important from the standpoint of science are about 100 foundations—nearly half of all grant-making institutions—that furnish money grants to other agencies to carry on research in the natural and social sciences. A smaller group of foundations give scholarships and fellowships to individuals, while others operate laboratories. The total number active in supporting science in one way or another cannot be determined more precisely, because many foundations have nonspecific charters and shift their fields of activity from time to time.

Detailed financial data were obtained from 240 foundations. These had capital assets totaling $1,539,966,000 and spent $56,779,000 last year for purposes covered by their charters By far the largest foundations were the grant-making agencies. Numbering only 117 out of the 240 that made public their financial reports, grant-making foundations had assets of $1,278,252,000 and spent $51,976,000.

Nearly half the 899 foundations covered in the survey publish no information on either their finances or their fields of activity. Their silence, the survey points out, is endangering the tax-exempt status of the private foundation.

Meeting in July

AMERICAN Society of Civil Engineers. Mexico City. July 13-15.

LOW TEMPERATURE PHYSICS

At normal temperatures matter is in ceaseless thermal motion. Physicists have accordingly reduced it almost to absolute zero to expose some subtle properties that are otherwise obscured

by Harry M. Davis

IT was quitting time at the National Bureau of Standards. Most of the technicians were joining their car pools to enter the stream of traffic on Connecticut Avenue, but in the low-temperature laboratory a fresh batch of the coldest fluid was ready to be siphoned from Russell Scott's home-made helium liquefier. It was J. R. Pellam's turn to draw the precious refrigerated liquid, and dinner could wait. As he set the vacuum-insulated flask of liquid helium carefully inside another vacuum-insulated flask of liquid oxygen, connected the vapor-pressure thermometer and adjusted a clamp on the hose to the vacuum line, Pellam made a remark that explained much of the fascination that low-temperature physics, or cryogenics, has for its workers. "We are beginning to learn," he said, "what lies beyond the thermal chaos."

Thermal chaos is more than a figure of speech. It is the random movement of molecules in every substance we touch, in the air around us, in our very protoplasm. It is thermal chaos, in fact, that makes life possible. Without it molecules could not collide and interact in the ceaseless round of metabolism.

One of the greatest discoveries of the 19th century was that heat was not a "subtle fluid," as earlier philosophers had thought, but a condition of matter. In England, where thermal chaos was first harnessed to drive the steam engine, scientists began to pronounce in their lectures that "heat is a mode of motion." It was a triumph of this period that the laws of the pressure, the volume and the temperature of gases could be drawn from the statistics of vast numbers of particles moving and colliding in a fortuitous fashion The totality of their impacts pushed the moving piston, the totality of their kinetic energies was their content of heat.

Normally we experience the smooth, regular result of the law of averages working over enormous populations of moving molecules. We have the steady reading of a thermometer, the smooth spinning of a steam turbine, the definite speed of sound in air of a given temperature. Under certain conditions, however, the thermal chaos can be seen and heard. It can be seen in the microscope, under which, as the British botanist Robert Brown observed more than a century ago, tiny particles are never entirely still. Brown's name is perpetuated in this Brownian movement.

It is easier to listen to thermal chaos. The only necessary apparatus is a radio set. The noise heard when the set is not tuned to a station and the volume is turned up is nothing but the amplified effect of electrons boiling at random in the thermionic tubes. In fact, the thermal agitation that the power engineer defines as heat has a less flattering definition in the vocabulary of the communication engineer. It is "pure noise," the frustrating factor that limits the sensitivity of a receiver, since more amplification will build up the set's own electronic noise as much as the incoming signal. One of the practical applications that can now be envisaged from low-temperature research is the use of a refrigerated crystal, free of internal noise, to pick up radio signals far fainter than the threshold of a heated radio tube.

Accepting the fact that matter at familiar temperatures is in a state of thermal chaos, there are two ways of bringing order out of it. The usual way is to deal with vast molecular populations, where the laws of probability work out so that individual fluctuations are not noticeable. This, perforce, will continue to be the usual way of doing business with nature. The other way, which is pursued in cryogenic laboratories, is to remove as much as possible of the energy of motion, silence the "pure noise" of random movement, and see what happens when matter approaches utter stillness.

We shall see that below the temperatures of thermal chaos matter behaves in strange and excitingly different ways, exhibiting novel responses to the stimuli of electricity, magnetism and heat. There are superconductors of electricity, screens against magnetism, new forms of wave motion, and, in the case of helium, a "fourth state of matter" which cannot be strictly defined as either a liquid, a solid or a gas. These odd phenomena have made low temperatures one of the most fascinating frontiers of current physical research.

Most U.S. work at this frontier is sponsored by the Office of Naval Research, the scientific administrators of which have not demanded immediate practical results, military or otherwise. It is enough for them that there is knowledge to be gained that will lead to a better understanding of metals, crystals, liquids and gases, of electrical resistance

and induction, of electrical conductors, semiconductors and superconductors Asked about the usefulness of it all, they will refer to the classical cliché, "What good is a newborn baby?"

Low Temperatures in Industry

We might first examine some of the baby's older brothers, earlier progeny of low-temperature research that have grown to healthy maturity On the long road from zero degrees Centigrade (the freezing point of water) to zero degrees Kelvin ("absolute zero," 273.16 degrees lower), low-temperature research has brought about such things as household refrigeration and the mass production of pure oxygen and nitrogen from liquid air

Liquid oxygen represents the nearest large-scale commercial approach to the temperatures of the cryogenic laboratory. Its temperature is not far above the laboratory range. At atmospheric pressure oxygen's boiling point is −182.97 degrees C., only 90.19 degrees above absolute zero.

When the first detectable mists of liquid oxygen were obtained in 1877, it could hardly have been predicted that the product would be distributed in tank-car loads for use in oxyacetylene torches; or that "lox," as the aviators have abbreviated it, would permit the fast burning of fuel in the first long-range rocket, the V-2, and the first supersonic airplane, the X-1 The Linde Air Products Company, pioneer producer of liquid oxygen, began by shipping oxygen as a gas under a pressure of 2,200 pounds per square inch, and still does so to smaller users. For bigger customers, it ships liquid oxygen at −182.97 degrees C. (or −297 degrees on the Fahrenheit scale more familiar to industry). A single tank car carries as much oxygen as 11 freight-car loads of the pressurized gas cylinders.

The big prospect of the air-liquefaction industry lies in the possible use of moderately pure oxygen, or oxygen-enriched air, to speed up combustion in industry, notably in the making of steel. Four fifths of air is inert nitrogen, and this natural mixture can stand artificial improvement for the purposes of combustion. The production of oxygen from the air, of course, leaves four times as much nitrogen as a by-product, and commercial applications for the latter are being sought.

One such application is for assembling products where a tight fit is needed. A common method is expansion fitting, similar to the housewife's trick of putting a tight jar under hot water to expand and loosen the cap. The outside member is expanded by heat and shrinks back tightly on the inside part as it cools. The use of liquid nitrogen, which will quickly chill a piece of metal to −320 degrees F., makes it possible to shrink the inside member first, put it in place, and let it expand to a tight fit as it returns to room temperature. Liquid oxygen has been used for shrinking, but it creates an explosion hazard in the atmosphere. Liquid air has the same disadvantage because the nitrogen boils off first, leaving liquid oxygen again.

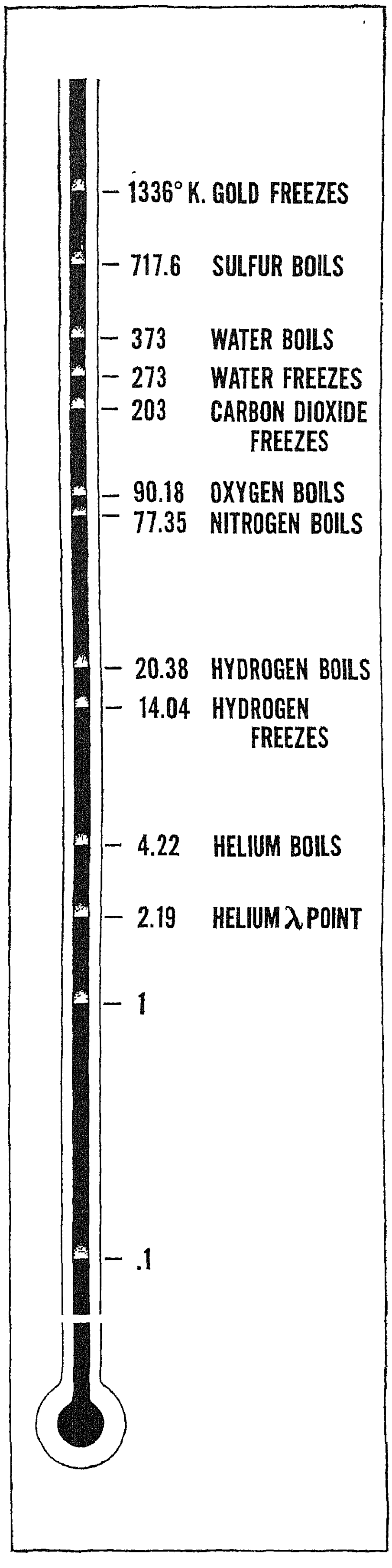
Liquid air, liquid oxygen and liquid nitrogen have thus earned their keep. They are also important as auxiliaries in reaching the temperatures of liquid hydrogen and liquid helium, either to chill them or to interpose an insulating barrier between them and the outside air In the history of cryogenics, their liquefaction served as milestones along the road toward the still unattained and probably unattainable goal of absolute zero.

The Absolute Scale

Thus far we have used, in about the manner they are normally employed in science and industry, three different scales of temperature and three different definitions of zero. The three scales more or less reflect the history of man's understanding of heat and cold. Gabriel Daniel Fahrenheit, the German physicist who made his living in England and Holland by manufacturing meteorological instruments, set zero at the lowest temperature he could obtain by a freezing mixture. On this scale, "absolute zero" is −459.6 degrees F. In 1742, six years after Fahrenheit's death, the Swedish astronomer Anders Celsius proposed a scale with the freezing point of water at atmospheric pressure as zero and its boiling point as 100. This scale, usually called Centigrade, was officially renamed the Celsius scale last year by the Ninth International Conference on Weights and Measures in Paris. Since the abbreviation C. is retained, the change is not momentous. On the Centigrade or Celsius scale, absolute zero is −273.16 degrees C.

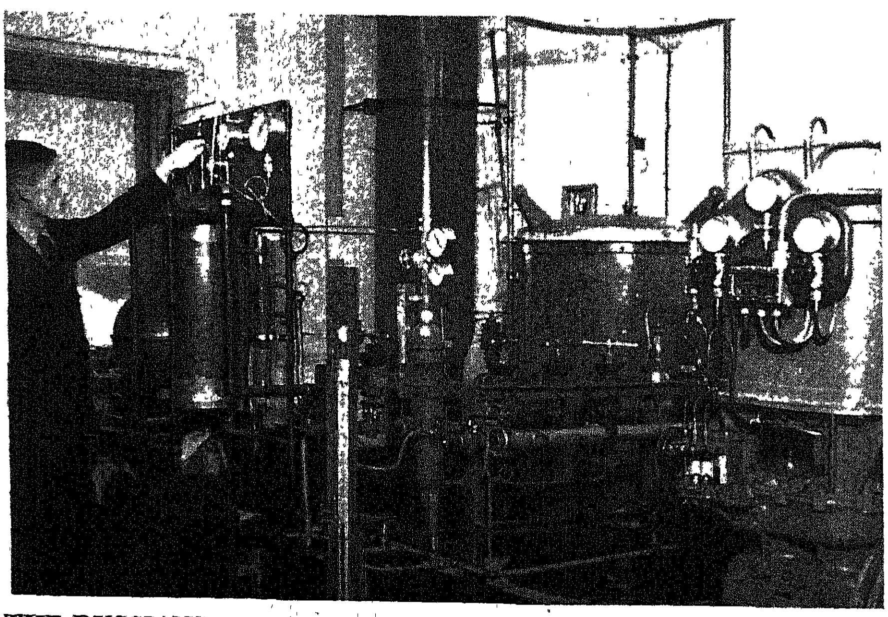
Both the Fahrenheit and Celsius scales are essentially arbitrary, like the pound, the kilogram, the meter or the mile. In 1848, with the increasing thermodynamic sophistication of science, the great Lord Kelvin proposed his "absolute" scale. This retained the Celsius degree but shifted zero to its location in nature. Absolute zero is by definition zero degrees Kelvin, and degrees K. will be used henceforth in this article.

No one has ever reached absolute zero, and it may be stated with a fair degree of confidence that no one ever will. The argument for this is analogous to the indeterminacy principle encountered elsewhere in physics In order to measure the temperature of a substance, some energy must be exchanged between the substance and its environment. The moment we have energy,



THERMOMETER of significant temperatures in physics is plotted by logarithmic scale to show the detail of the regions close to absolute zero.

THE ENGLISH were among the pioneers of low-temperature physics. This photograph, from David Shoenberg of the Royal Society Mond Laboratory at Cambridge University, shows Sir James Dewar, liquefier of hydrogen.



THE RUSSIANS have been active in the field. The Soviet physicist Peter Kapitza built the first helium-engine type of cryostat. In this picture the engine is at the left. In it the helium cools itself by pushing a piston.

however, we are not at absolute zero The term implies the absence of thermal energy. Another argument is that the problems of heat removal increase as we get closer to absolute zero It is not terribly difficult to cool oxygen from its room temperature of about 300 degrees K. to its boiling point of 90 degrees. It is a good deal harder to get to the hydrogen boiling level of 20 degrees. It takes much more effort to attain the liquid-helium level of 4.2 degrees at atmospheric pressure, or 1 degree in a good vacuum. It requires additional magnetic apparatus to chill the helium to .01 or .001 degree. Physicists are still pondering the problem of magnetically lining up the nuclei of atoms to get to the millionth-of-a-degree range. As for closer approaches to the goal of absolute zero, the obstacles appear to be absolutely infinite.

This ultimate barrier does not deter low-temperature investigators any more than the infinite distances of the universe intimidate astronomers. The low-temperature workers have an advantage. From the properties of matter which are dependent on temperature, they know at least where their limit lies.

Descending the Scale

The chronology of man's descent into the depths of temperature goes back to the latter part of the 18th century. The issue then was not low temperature as such, but the question of whether all gases could be liquefied. Some experimenters used pressure, others used cooling, others used both. Ammonia gas was liquefied in 1798 Then, at the Royal Institution in London, Michael Faraday turned his experimental genius to the problem, and in rapid succession liquefied chlorine, carbon dioxide, nitrous oxide and other compounds. By 1835 the French chemist C. Thilorier had produced solid carbon dioxide, the "dry ice" of today.

But try as they might—and they tried mightily by squeezing gases with pressures of hundreds and even thousands of atmospheres—the early experimenters could not liquefy the three most common gases: oxygen, hydrogen and nitrogen. These became known as "permanent gases," apparently resisting the law that any kind of matter could be found in the three states of solid, liquid, and gas. Not until 1869 was it realized that each gas has its critical temperature, above which no amount of pressure will reduce it to a liquid. For the three gases mentioned, the critical temperatures are now known to be:

Oxygen	154.4 degrees K.
Nitrogen	126.1 degrees K.
Hydrogen	33.3 degrees K.

Note that these are the temperatures at which liquefaction will occur under

compression At atmospheric pressure the corresponding temperatures are lower.

Oxygen	90 1 degrees K.
Nitrogen	77.3 degrees K
Hydrogen	20 4 degrees K

To make this list of low-temperature gases complete we may push ahead of our narrative to the discovery of helium in the sun, its extraction from rocks and gas wells on the earth, and its liquefaction at a critical pressure at 5.2 degrees, and at atmospheric pressure at 4.2 degrees.

The liquefaction was achieved in the order of descending temperatures. Oxygen was liquefied in 1877, nitrogen in 1883, hydrogen in 1898. One thing had led to another physically as well as chronologically, for the experimenters generally employed one liquefied gas to cool the next. It was with the aid of liquid air that in 1898 Sir James Dewar brought hydrogen to the temperature from which it could be further cooled to its liquefaction. Thus by the end of the 19th century all the "permanent" gases had been liquefied.

The 20th-century interest in these gases has largely passed from physics to industry. The applications of liquid oxygen and nitrogen have already been discussed. Liquid hydrogen may also have an important future, if experiments at Ohio State University point the way to interplanetary rocket propulsion. A miniature rocket engine has been running there, fueled by liquid hydrogen burned by liquid oxygen. This combination yields the highest exhaust velocity yet attained.

The man who first liquefied hydrogen also invented a device used in every cryogenic laboratory. The Dewar flask, or, to use the common noun, the dewar, is the laboratory counterpart of the Thermos bottle. The double thickness of silvered glass enfolding a vacuum prevents the transfer of heat, thus keeping coffee hot and hydrogen cold. Modern laboratories usually employ a double dewar: a dewar filled with liquid helium immersed in a dewar filled with liquid hydrogen or liquid air. In such an arrangement the barriers to heat conduction, reading from the liquid helium outward, are: glass, silver, vacuum, silver, glass, liquid air or hydrogen, glass, silver, vacuum, silver, glass.

The story of modern research at the lowest possible temperatures is the story of helium, first discovered on earth at the end of the 19th century. At the celebrated cryogenics laboratory of the University of Leiden, run for many years under the benevolent Dutch dictatorship of Heike Kamerlingh Onnes, helium was reduced to the liquid form for the first time on July 10, 1908. It was the last of the gases to yield to man-made cold. By pumping vapor away from the surface of liquid helium, thus cooling the latter by evaporation, Kamerlingh Onnes eventually reached a temperature within .7 degree of absolute zero. This is still about the lowest that can be attained without resort to the newer techniques that will be described presently.

Methods of Chilling

There are a number of ways of achieving low temperatures, and these may be used in various combinations. First there is the refrigeration cycle of the household refrigerator. a vapor is compressed by a pump and cooled by circulating water, to which it yields its heat. This condenses the vapor into a liquid which is allowed to evaporate again, removing heat from the interior of the refrigerator. The method does not suffice to reach truly low temperatures.

One of the classical methods is a simple sequence of compression, heat exchange, and expansion. The gas to be cooled is compressed by a pump, a process which causes it to get warmer. The added heat is removed by passing the gas through a pipe surrounded by another pipe containing a colder liquid. In making liquid air, for example, the cooling may be done by water, in making liquid hydrogen, the cooling may be done by liquid air, and in making liquid helium, the cooling may be done by liquid hydrogen. The compressed and cooled gas is now allowed to expand through a narrow orifice, which cools it even more.

This cooling by expansion was first proposed by the British physicists James Prescott Joule and William Thomson, later Baron Kelvin of the degree K., and for them it is named the Joule-Thomson effect. Often the gas cooled by the foregoing process is used to cool the incoming gas, so as the process goes along the gas gets colder and colder until it finally liquefies. In the case of helium the Joule-Thomson effect operates only after the gas has been cooled to the temperature of liquid hydrogen.

Another method, theoretically obvious long ago but only recently applied on a major scale, is to allow helium to drive an engine so that it gives up its thermal energy in mechanical motion. Helium at room temperature is something like steam far above the boiling point of water. Under the right conditions it will drive a small version of a steam engine, and just as the spent steam turns to water the exhaust helium turns to liquid. All this is easier said than done because no lubricant will serve to ease friction at the temperature of liquefying helium, and the engine must be built with such close mechanical tolerances that only a thin stream of helium gas will escape between the piston rings and the cylinder wall.

Peter Kapitza, the Russian physicist who is now presumably engaged in atomic research, developed such a helium engine while working in England before the war He chilled helium to the temperature of liquid air and ran it through a one-cylinder engine from which it emerged as a liquid. C. T. Lane of Yale University built a similar apparatus, thus establishing one of the first few laboratories in the Western Hemisphere capable of working with liquid helium. E F. Burton of the University of Toronto and W F. Giauque of the University of California had earlier used other methods of attaining such temperatures.

Until only a few years ago every low-temperature laboratory had to build its own low-temperature apparatus. The research worker had to be a first-class refrigeration engineer, one result being that every cryogenic apparatus was unique. Another result was that there were few cryogenic laboratories. The situation has changed with the development of a helium-engine type of apparatus by S. C. Collins of the Massachusetts Institute of Technology. It is a two-cylinder engine, with the cylinders arranged so that the cold exhaust gas of one cools the intake gas of the other. With this apparatus, and without the assistance of intermediate coolants such as liquid hydrogen or liquid air, it is possible to proceed directly from the temperature of cold tap water to that of liquid helium. The helium is compressed in powerful compressors, cooled by water and sent through the two-stage engine.

An ex-student and co-worker of Collins, D. O. McMahon, left M.I.T. to join the laboratories of Arthur D. Little, Inc., a few blocks up Memorial Drive in Cambridge. There, in addition to carrying on low-temperature research of his own, McMahon has put the Collins Helium Cryostat into what, for this field, can be regarded as mass production. Nineteen of the machines have already been shipped to laboratories all over the country. The Naval Research Laboratory alone has three. This means that a physics laboratory, having decided to go into low-temperature research, does not have to wait a year or two until its physicists build a cryogenic apparatus and perfect it. At a cost of about $22,000, the laboratory can be in business almost immediately. Collins is now building a gigantic cryogenic apparatus for himself, about which workers in other laboratories speak with awe. The rumor is that it will provide a working space, all at the temperature of liquid helium, as big as a large refrigerator.

The Properties of Helium

Helium might be called the "less" gas. It is colorless, odorless, tasteless, and so nearly weightless that its principal use is for the inflation of balloons. Hydrogen

is even lighter, but hydrogen burns, as it did in the Graf Zeppelin. Helium is one of the "noble" gases, it disdains to react with other elements It was first discovered in the spectrum of the sun, where it is believed to be the final inert product of the nuclear reaction which is the source of the sun's radiant energy On earth it is created by the radioactive breakdown of heavy elements such as uranium and radium. Their alpha rays are the nuclei of helium atoms, consisting of a family of two protons and two neutrons. These particles capture a pair of electrons as satellites and become helium atoms Nuclear physicists sometimes reverse the process, stripping away the electrons to use the alpha particles as projectiles in such machines as the cyclotron.

On the current frontier of cryogenic research, helium plays a dual role. As a liquid, it is a curious and fascinating substance that is occupying the full attention of many experimenters and theorists. As a cold liquid bath, it causes substances immersed in it to exhibit the curious and fascinating properties of all matter shorn of most of its thermal chaos.

The fascination of liquid helium itself derives from phenomena that occur when its temperature is reduced to 2.19 degrees K. Picture a dewar of freshly made liquid helium inside a dewar of liquid air. There are narrow vertical slits of unsilvered glass on both dewars, and when they are turned to coincide, a window is formed through which the experimenter observes the liquid. Both the liquid air and the liquid helium, frigid though they be, are boiling just as water boils in a teakettle at 373.1 degrees K. The air bubbles are large; the helium bubbles are small. The outside dewar of liquid air is vented, keeping it safely at atmospheric pressure. The inside dewar of liquid helium is connected to a vacuum line which draws off the vapor so that the remaining liquid will get still colder.

As the helium reaches 2.19 degrees, the boiling seems suddenly to stop The surface is as smooth as glass, although jellylike ripples may run across it. Its temperature continues to drop. Vapor is still formed and drawn away, but it escapes without noticeably ruffling the surface. The helium has evidently entered a new state. Because of many other curious properties, it has been given the name helium II.

Is it still a liquid? Liquids have viscosity, and in some respects helium II has none. It flows through the narrowest of orifices. Low-temperature workers were annoyed by the difficulty of making leakproof containers for it until they realized that this was demonstrating a new kind of matter.

Is it a gas? Helium II atoms are more mobile than the atoms and molecules of gases. But they obey the law of gravity as a liquid does, remaining at the bottom of containers. They also form a surface which will seek its own level more diligently than water

Is it a solid? One would expect that if a substance liquefies at 4.2 degrees and undergoes another change of state at 2.19 degrees, the second change would be freezing. In fact, when this state was discovered there were attempts to show that it was some kind of crystalline array. There is no solid as agile as helium II; it flows, pours or dances through the narrowest crevice. Besides, there is a solid helium. While it cannot be obtained under atmospheric pressure with the lowest temperatures yet reached, it has been obtained by building up the pressure to 25 times that of the atmosphere.

Physicists have worked out a diagram of the states of cold helium that may be seen at the top of page 36. Because the intersection of two of the lines on the graph is reminiscent of the shape of a slightly tilted Greek letter λ, or lambda, cryogenics has adopted the term "lambda point" for the transition to helium II.

If the journey past the lambda point does not take us to a solid, a liquid, or a gas, what is helium II? Physicists have been driven to calling it "the fourth state of matter." Some of them describe it as "the quantum fluid," of which more later. The phenomena that urgently require explanation are "the creeping film," "the fountain effect" and "second sound."

Let us begin with the case of the creeping film. If the bottom of a small vessel is placed in helium II, an unlikely thing happens. The liquid helium climbs up the sides of the vessel and fills it to the same level as the surrounding surface. If the vessel is then lifted, the helium climbs back over the edge and down to the surface again. Water or any other well-behaved liquid will, of course, find its level but such liquids need a pipe or a primed siphon. In some peculiar way helium II gets around on its own.

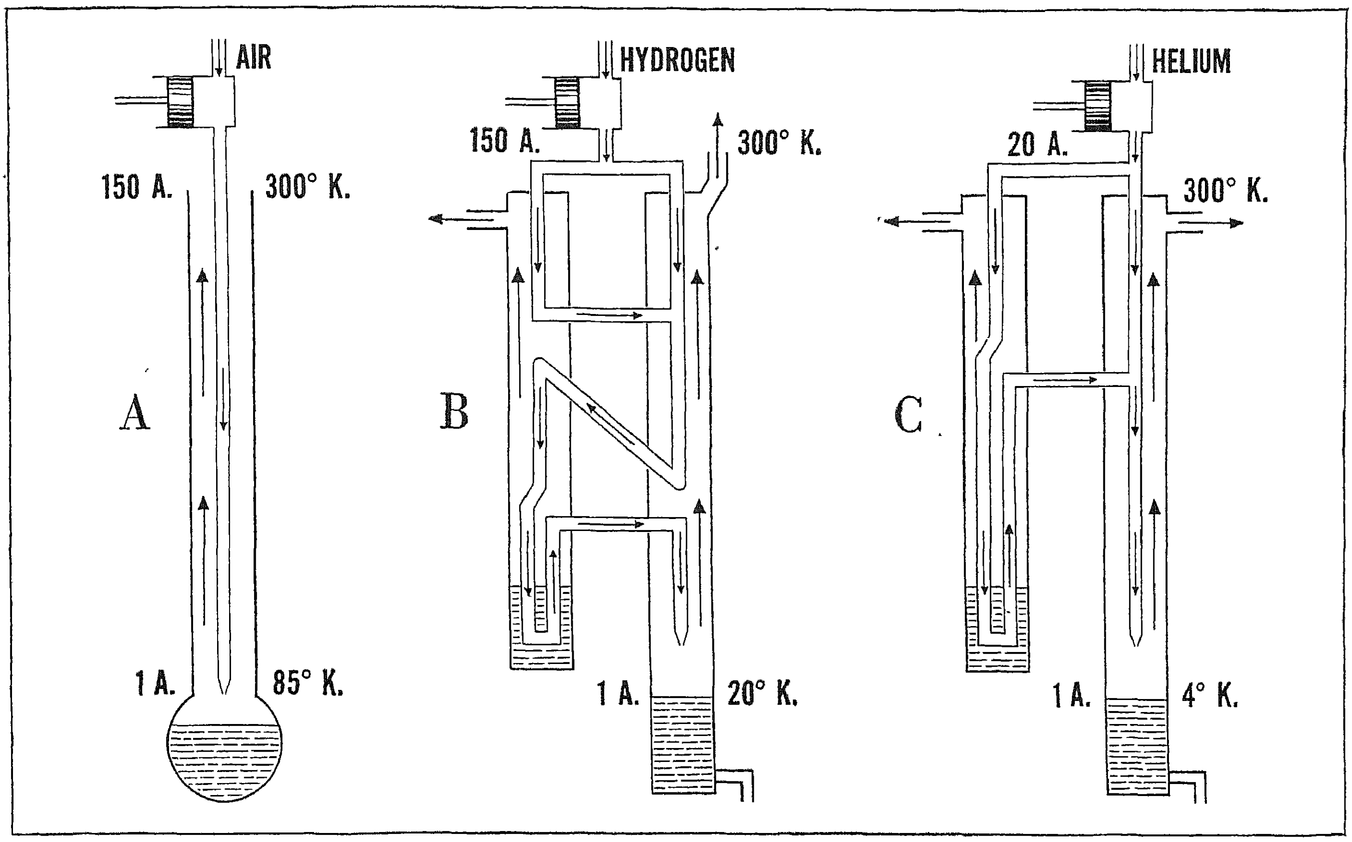
The fountain effect occurs when a vessel which narrows to fine tubes at top and bottom is lowered into helium II. Sometimes the bottom of the tube is filled with finely ground powder. Helium II infiltrates the lower tube with ease If the vessel is then warmed by light, helium will spurt through the upper tube in a spectacular fountain.

Second sound is related to the fact that helium II is a superlative conductor of heat. Warm one end of a vessel, and a pulse of heat will be quickly conveyed to the other end. This phenomenon might be described as a heat wave propagated quickly through the coldest kind of matter. Because it is analogous to the pressure waves of sound, the Russian physicists who first discovered the phenomenon in Moscow near the end of the war called it second sound. Its existence, which had been predicted by both Russian and American physicists, was soon confirmed by Lane at Yale. The phenomenon is now being studied intensively in many laboratories. Pellam, for example, sends pulses of heat through helium II at different temperatures, and by electronic methods has displayed the lapse of time between the transmitted and received temperature signal on a cathode-ray tube.

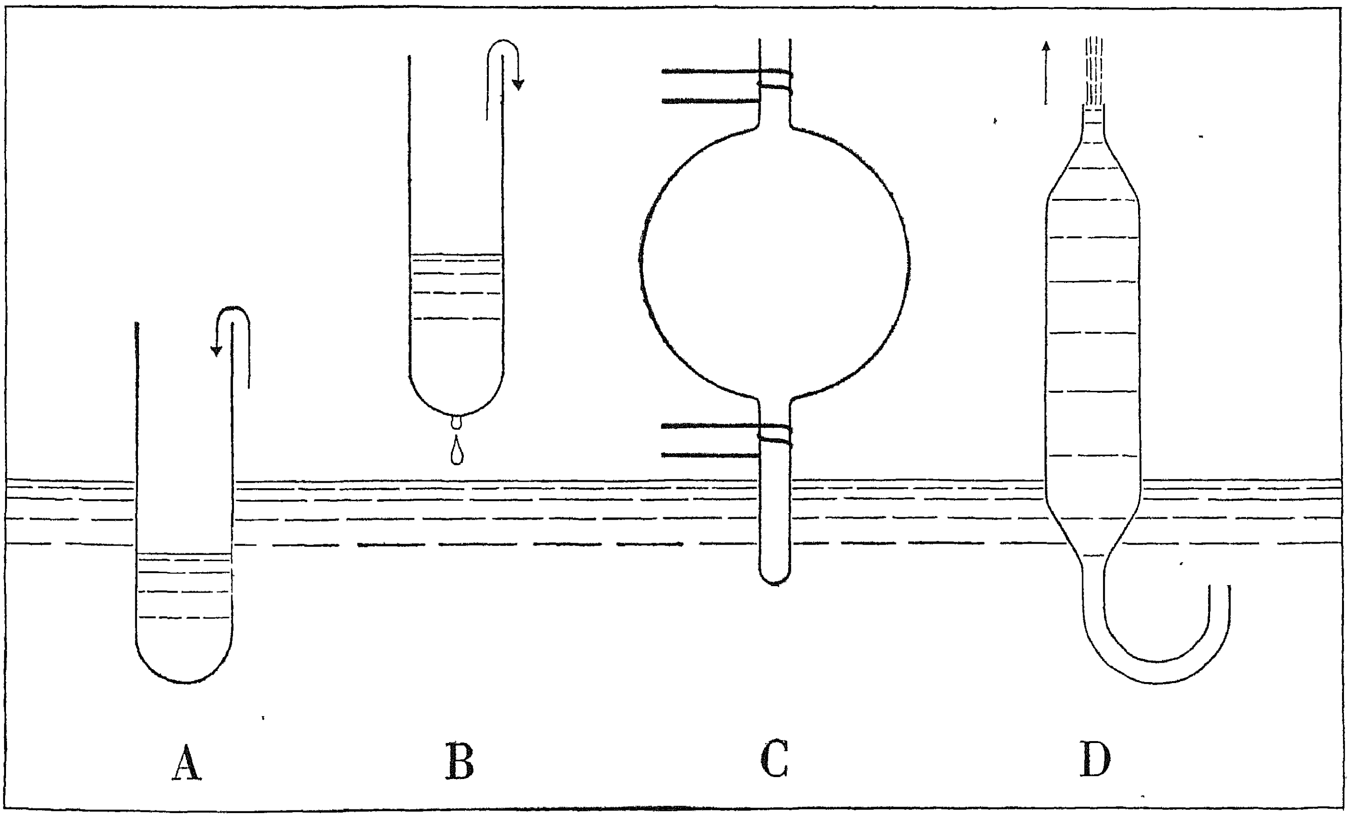
In cryogenics, unlike other branches of physics, there appears to be a free exchange of information among nations. U S. low-temperature workers keep a close watch on the Russian journals. A typical U.S paper in low-temperature physics will bear footnote references to "J. Phys. U S S.R.," citing the theories and experiments of Kapitza, Landau, Peshkov and Andronikasvili. In this coldest of all scientific disciplines, the cold war is directed against the secrets of nature.

One of the most revealing eccentricities of helium II was predicted by Landau and in 1946 was observed by Andronikasvili. His experiment was to rotate a vessel of chilled helium and to measure its inertia. As the temperature dropped below the lambda point, the vessel's resistance to acceleration rapidly decreased. The only explanation was that a considerable number of the atoms in the helium II were not participating in the rotation. This component, as Collins puts it in a recent survey, "does not take part in the rotary motion, but glides through the interpenetrating atmosphere of normal helium atoms without friction." It is as though a man in a tightly packed crowd could remain motionless while the crowd surged past him.

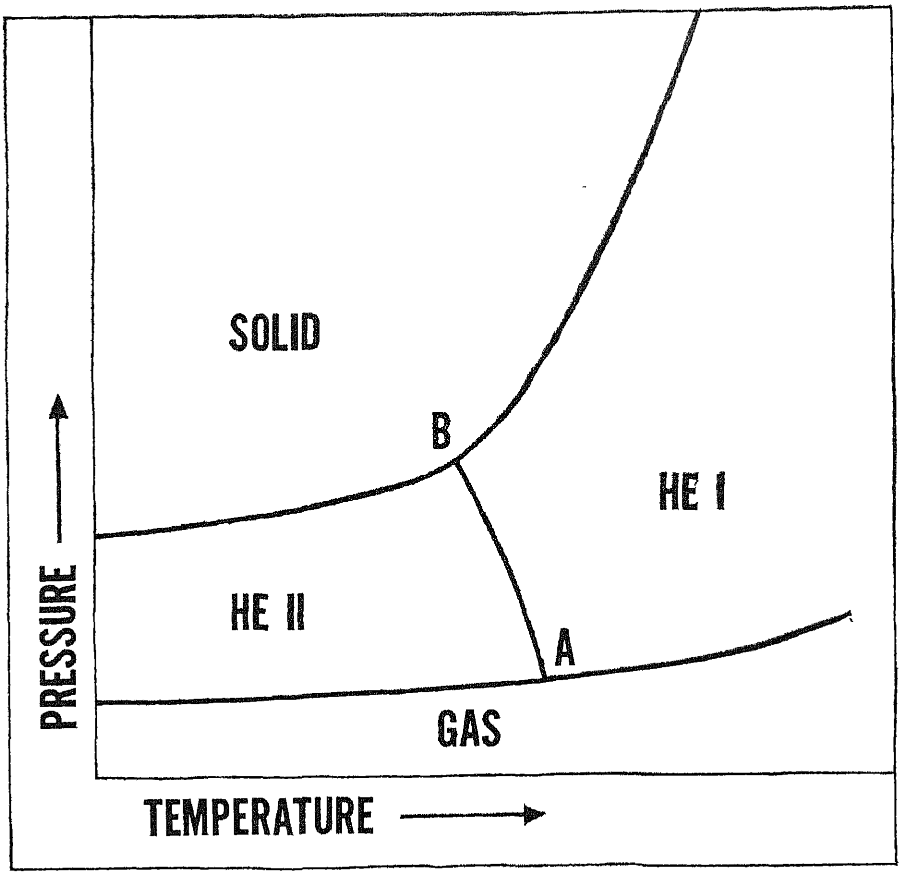
What is the explanation for these strange occurrences in helium II? Physicists have adopted the concept that, even at a degree or two above absolute zero, an increasing proportion of the helium atoms drop to a "zero energy state." It is here that the concept of the quantum fluid is necessary. The quantum theory states that the energy of an atom cannot be gained or lost continuously but must come in certain prescribed amounts. A graph showing the loss of energy with temperature would be a series of steps rather than a smooth curve. At ordinary temperatures the steps are so small in proportion to the total thermal energy that the individual atomic quanta do not mar the smoothness of the curve. At a degree or so above absolute zero, however, we are on the last few steps from the bottom of the staircase. If more energy is withdrawn, it is no longer possible for all of the atoms to shift to lower levels while maintaining a normal "probability distribution." Some of the atoms on the step next to the bottom will lose all their remaining thermal energy with the emission of a single quantum. They will drop to the



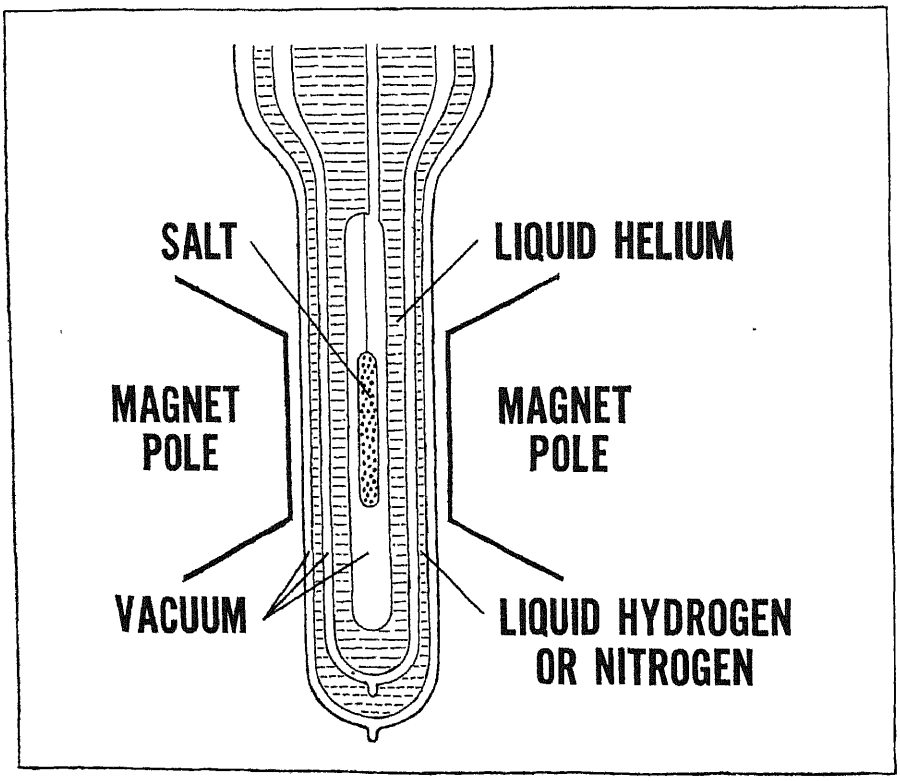
LIQUEFACTION of air was accomplished in early apparatus (A) by compressing it to 150 atmospheres, allowing it to expand through a nozzle, and circulating the gas thus cooled around the incoming gas. The latter was then made progressively colder until it liquefied. Lower temperatures of liquid hydrogen and helium were attained by the same means (B and C) except that gas was circulated through another gas already liquefied.



LIQUID HELIUM behaves strangely when it is cooled to 2.19 degrees K. If a vessel is lowered into it (A), the helium climbs in. If the vessel is lifted out of it (B), the helium climbs out. The speed with which this film travels may be measured by timing its arrival at the top wire on a glass bulb (C). If helium is allowed to enter a fine tube at the bottom of another vessel (D), it will spurt from the tube at the top when light is shined on it.



PHASE DIAGRAM of helium shows the relationship of helium II to the usual three phases of an element: gas, liquid and solid. The transition from helium I to helium II is called the lambda point because the intersection of line AB with others is roughly comparable to the Greek letter λ, or lambda.



LOWEST TEMPERATURES are attained by suspending a certain salt in a container of liquid helium between the poles of a magnet. Helium gas is first allowed into vacuum chamber to cool salt. Gas is removed and salt is further cooled when magnet lines up molecules and stills thermal motion.

"ground state," while the others remain one, two, or more steps up

These ground-state atoms are presumably responsible for the many foibles of helium II. The colder the helium, the more of its atoms will be in the ground state Thus there is a mixture of two fluids, a normal fluid and a "superfluid," which do not interact with each other except that with the loss or gain of heat an atom can go from one state to the other

The ground-state or superfluid atoms are believed to remain aloof when a vessel of helium II is rotated. It is they that find their way through the narrowest crevices, that creep up the walls of containers. The fountain effect may occur on a one-way street policed by a kind of quantum traffic cop. The ground-state atoms proceed through the narrow channel, and at the far end are warmed by an outside source of energy. This raises them to a normal state in which they cannot get back through the narrow entrance. Meanwhile more ground-state atoms are coming in, with the result that enough pressure might be built up to create a fountain

Second sound is likewise explained by the transformation of ground-state atoms outward from the source of heat in a sort of wave front. The ground-state atoms move back to replace those that have been heated. Then they slide through the normal atoms without friction.

These are the somewhat crude visualizations of a theory based on quantum-mechanical mathematics. The theory was derived by Laszlo Tisza of M.I.T. and Fritz London of Duke University from a mathematical generalization of Albert Einstein and the Indian physicist S N. Bose. The "Bose-Einstein statistics," the explanation of which is beyond the scope of this article, were expected to apply to the abundant isotope of helium which has an atomic weight of 4, but not to the rare isotope which has an atomic weight of 3. The theorists predicted that if a supply of He^3 became available, it would not enter the quantum-fluid condition at low temperature. In other words, experimentalists could expect no He^3 II.

Several groups have therefore attempted to achieve the separation of helium 3 by means of the fountain effect and similar processes depending on superfluidity. At Ohio State and Yale a concentration of helium 3 was obtained by utilizing the fact that it did not act as a superfluid below the lambda-point temperature for ordinary helium.

Meanwhile the powerful devices at the disposal of the Atomic Energy Commission were put to work on the problem. In the nuclear reactor, hydrogen 3, or tritium, was being made by transmutation As it decayed by radioactivity it turned into helium 3. With this first pure supply of the rare helium isotope,

the customary tests for a superfluid were re-enacted.

Before revealing the denouement to those readers who did not read it in *The Physical Review* or in the reports which appeared in some newspapers and magazines, the suspense may be heightened by pointing out that this was to be the crucial test of the London-Tisza, or "American," theory of superfluidity as opposed to that of Landau in Moscow. Both theories had accounted in different ways for phenomena observed up to that time, and both had scored successful predictions of earlier experimental results.

As recently as August of last year Tisza, writing in *Physics Today*, said: "If the Bose-Einstein statistics is essential for the superfluidity of the abundant isotope He^4, then He^3 should be not superfluid. . . . On the other hand, according to the other theories, no essential difference can be expected for the two isotopes."

Tisza concluded: "If the separation of He^3 in sizable amounts is indeed possible, the study of this substance would be of considerable interest. It would be the only case where two stable isotopes have radically different properties. It seems very likely that He^3 cannot exist in the liquid state at all. Such a liquid should have a vanishing dynamic viscosity and a high kinetic viscosity. Either we will have a liquid of entirely unheard-of properties, or the system will avoid the dilemma of the large and small viscosities by not liquefying at all, but will either freeze or rather stay a gas at vanishing pressure and temperature. It is to be hoped that the experimental decision of this question will be forthcoming before long."

The experimental decision came from the laboratories of the AEC at Los Alamos in January, 1949. S. G. Sydoriak, E. R. Grilly and E. F. Hammel showed that helium 3 does become a liquid, at 3.2 degrees. In March, however, D W. Osborne, B. Weinstock and B. M. Abraham of the Argonne National Laboratory announced that helium 3 does not pass over to a superfluid in the same manner as helium 4, even when it is cooled to 1.05 degrees. Thus the principal London-Tisza prediction of the differences between the two isotopes was borne out. Tisza's further prediction that helium 3 would not liquefy at all was obviously not. Whether liquid helium 3 will have "entirely unheard-of properties," opening a new vista of research as absorbing as that of He^4 II, remains to be seen. The wide range of possibilities that Tisza permitted himself to suggest in advance of the experiment is a good index of the superfluid state of low-temperature physics. Almost anything can happen when helium 3 is made still colder. Workers outside the AEC are eagerly waiting their chance to try it, meanwhile exploiting the proved difference between the two isotopes to do some more efficient concentration by the thermal methods available to them. Meanwhile the astonishing disparity between two substances which differ only by a single neutron in the nucleus will give the nuclear physicists something to ponder.

Superconductivity

Perhaps the most impressive of all phenomena at temperatures within a few degrees of absolute zero, and certainly the most intriguing from the practical engineer's point of view, is the conversion of certain metals into superconductors At a particular temperature, which is different for each of the metals involved, a wire will lose all measurable resistance to the flow of electric current, and a sheet or disc will become an efficient screen against magnetism.

The fact that electrical resistance drops with falling temperature is no surprise. The resistance of a wire is generally proportional to its temperature; the filament of an electric light bulb will allow more current to enter when it is first switched on than after it becomes incandescent. This effect is put to work in electric-resistance thermometers, which have been standardized for both high and low temperatures. On this principle, the resistance of a wire should fall to zero at absolute zero, and the rate of decrease should be gradual as the temperature drops. This is what happens with the best of normal-temperature conductors. copper and silver.

In the case of many other metals, including some which are poor conductors at ordinary temperatures, resistance vanishes completely at a transition point from a fraction of a degree to several degrees above absolute zero. In these materials, which include mercury, tin and lead, a current once started will continue to flow practically forever unless something is done to destroy the superconducting condition.

The phenomenon is not entirely new. Kamerlingh Onnes discovered it in 1911 when he attempted to explore the lower end of the temperature-resistance curve. He tested solidified mercury in a bath of liquefied helium. Down to 4.3 degrees the mercury's resistance steadily decreased, as expected, to about one five-hundredth its value at the freezing point of water Then it suddenly dropped to less than a millionth of the normal value. Further research has shown that the purer the metal, the more completely and quickly does its resistance vanish.

The metallic superconductors since identified, in addition to mercury, tin and lead, include aluminum, zinc, thallium, indium, tantalum, gallium, thorium, titanium, columbium, vanadium, cadmium, zirconium, hafnium and lanthanum. Columbium, it was found in 1930, reaches superconductivity at the relatively high temperature of 9.22 above absolute zero.

Naturally such discoveries stirred the hope that superconductivity might be applied to reduce the huge problems of electric-power distribution which may be traced simply to electrical resistance. Efforts were made to find alloys and compounds in which the transition point would be nearer to practical temperatures. It was disappointing that most alloys showed a transition temperature even lower than those of their constituent elements. The greatest advance in transition temperature was scored with nitrides, carbides and borides of metals. The most successful of these is columbium nitride, which becomes a superconductor at around 15 degrees. This temperature does not necessarily require the use of liquid helium; it can be obtained with hydrogen boiling under reduced pressure.

Columbium nitride is being studied intensively at Columbia University and at Johns Hopkins University. During the war Donald H. Andrews of Johns Hopkins cleverly applied the properties of the transition state to make an extremely sensitive detector of infrared radiation. In a substance just on the borderline between the superconducting and non-superconducting condition, a slight change of temperature will cause an enormous change in electrical resistance. The on-the-verge material is also extremely sensitive to other outside influences of an electromagnetic nature, as was discovered when the Johns Hopkins superconducting bolometer began pouring music from a nearby radio station through its amplification system. The columbium nitride had acted as a detector of radio waves. It will also detect alpha rays, and steps have been taken to develop an extremely sensitive alpha detector.

The ability to detect or rectify an alternating current at low temperatures is not confined to columbium nitride. F. G. Dunnington and Bernard Serin of Rutgers University have subjected a helium-chilled tin wire to a combination of direct and alternating current which sweeps it in and out of the superconducting state as often as the alternating current reverses itself. At Yale, Amherst College and elsewhere, currents of assorted frequencies, including the microwaves that have been inherited from radar, are being employed to explore the mechanism of superconductivity.

The key to the situation appears to be magnetism. Probably the most rigorous definition of a superconductor is not its lack of resistance, but the fact that it is "a perfect diamagnetic." This means that, in direct contrast to a piece of soft iron, it rejects any attempt to impose a magnetic field upon it. Lines of force emanating from a nearby mag-

net or coil, which would be drawn in by iron, are pushed aside by a superconductor and made to detour around it.

Perhaps the most dramatic demonstration of this property is the floating magnet. If a permanent magnet is dropped into a dewar containing a lead plate immersed in liquid helium, it will not fall to the plate It remains suspended some distance above the superconducting lead. Occasionally it darts from side to side, but it does not come down.

The invisible strings controlling this strange marionette show are magnetic lines of force around the superconducting metal in the helium bath. The approach of the magnet generates electric currents in the surface of the lead plate. The magnetic effect of these currents precisely neutralizes and opposes that of the magnet, which has made a mirror image of itself in the surface of the superconductor.

Such curious powers are limited. If the field of the magnet is strong enough, it will penetrate the chilled metal. This destroys superconductivity. The more the temperature drops below the transition point, however, the more magnetic force it takes to destroy superconductivity Another way of disrupting the superconductive state is to send a sufficiently strong current through the metal This phenomenon is now interpreted as the result of the current's magnetic field. The lower the temperature in relation to its transition point, the more current the superconductor will be able to superconduct.

The most interesting demonstration of these characteristics occurs right at or just below the transition point. Here an intermediate state exists between superconduction and normal resistance, in which the balance can be swung one way or the other by small amounts of current It is here that some of the effects described earlier are achieved: the conversion of alternating current to direct, the detection of alpha radiation from a radioactive atom, of infrared radiation from a warm body, and of long- or short-wave electromagnetic radiation from a radio station.

What is the future of this department of low-temperature physics? Its workers believe they can learn more about the essential nature of electricity and magnetism, the behavior of which is in some ways simplified by the suppression of random thermal noise. They are already beginning to examine some long-established notions in a different light. The surprising thing, says one cryogenics investigator, is not that metals at low temperatures superconduct, but that those at ordinary temperatures do not.

Air is a superconductor of radio waves; glass is a superconductor of light; helium II is a superconductor of heat. Copper wires at ordinary temperatures, though they may be regarded as good conductors by the engineer, are in a sense opaque to electrons. The flow of current is impeded by friction, a good thing for lighting an incandescent lamp, but a bad thing for getting the current from the power plant to the lamp. The trouble is that the moving electrons interact with their medium. When certain metals become sufficiently cold, the electrons stop interacting and become as free as the ground-state atoms of helium II To them the metal becomes transparent.

Another view of superconduction is to think of every atom, in its own private sphere, as a superconductor. Electrons move in their orbits with no friction, much as the planets circle the sun with no resistance in the vacuum of space. In its own atomic orbit, there is nothing to stand in the electron's way. A superconducting piece of metal can be considered the joining of countless atoms in such a manner that each electron finds a superorbit, with the rules of quantum mechanics barring any other particle from trespassing upon its right of way.

The Lowest Temperatures

While scores of physicists are exploring superconductivity and helium II, extending the work of those who attained the temperatures of liquid helium, others are venturing into the remote region between zero and 1 degree K. In the approach to absolute zero, nature's opposition is fierce. A formidable technique must be brought into play: adiabatic demagnetization.

This remarkable procedure was suggested independently in 1926 by Peter J. W. Debye, now head of the Cornell University chemistry department and no longer a worker in cryogenics, and W. F. Giauque, whose elegantly equipped laboratory at the University of California was the headquarters of the semiannual conference of ONR cryogenics contractors in February. Giauque and W. J. de Haas of Leiden perfected the method, and now most of the cryogenic laboratories are already using or building or planning the magnetic apparatus for getting below 1 degree K.

The method is skillfully based upon a special kind of thermal chaos: the random arrangement of the magnetic poles of individual molecules in substances known as paramagnetic salts. The molecules of most substances are magnetically neutral In those we are about to consider, such as iron ammonium alum, each molecule has one spinning electron which is not magnetically canceled out by other electrons in the same molecule. Under ordinary conditions, these molecular magnets are distributed in such a way that, on the large scale, they do cancel each other out. A handful of the salt will thus exhibit no inherent magnetism to an outside observer. If an outside magnetic field is applied, however, the molecules will tend to line up like tiny compass needles. The regimentation, being the antithesis of thermal chaos, squeezes some of the heat content out of the salt.

This may seem abstruse and remote, but the laboratory practice can be reduced to a procedure not unlike that outlined in a cookbook. Put a pinch of the salt, or as much as a pound of it, in the bottom of a dewar Pour liquid helium over it, perhaps a quart per pound Allow to cool by boiling the helium at lower and lower pressure, removing its vapor with a vacuum pump. Observe the lambda-point transition to helium II Keep the vacuum pump going until the temperature drops to 1 degree. Now apply a strong magnetic field. Allow time for the molecules to become fixed along the direction of the lines of force, and for the helium II to remove the heat. Remove the magnetic field. Observe the drop in temperature. Repeat.

The drop in temperature occurs in the final step of each such process While in the regimented magnetic state, the salt has given out heat that the helium carries away. When the magnetic field is removed (usually by swinging the dewar away from the fixed pole pieces), the molecules "relax," turning in all directions. This brings a concomitant drop in temperature. The salt needs heat energy to become disorderly, and this it absorbs from the helium, thus the helium-salt combination cools off during demagnetization.

Depending on the strength of the magnetic field, the temperature can be reduced to .1 degree, .01 degree and even 001 degree. Thus powerful magnets have been brought into cryogenic laboratories, just as they have been brought into the laboratories of nuclear physics. The Naval Research Laboratory at this writing is installing a powerful electromagnet with a field strength of 100,000 gauss, known as the Bitter magnet because it was originally designed for spectroscopic work by Francis Bitter of M.I.T. The turns of the magnetizing solenoid are thick copper straps which carry a current of thousands of amperes, are supplied with power by a 2,000-kilowatt generator, and must be cooled with a flow of 800 gallons of water per minute. If the cooling-water supply should fail, the copper would start boiling in a few seconds. Warren E. Henry, a physicist trained at Tuskegee Institute and the University of Chicago and an alumnus of Collins' laboratory at M.I.T., expects to cool as much as a quart of helium to .01 degrees absolute when the Naval Research Laboratory apparatus gets going on a full scale.

One of the things that happens at these temperatures is the formation, above the helium surface, of the world's most perfect vacuum. The vapor pres-

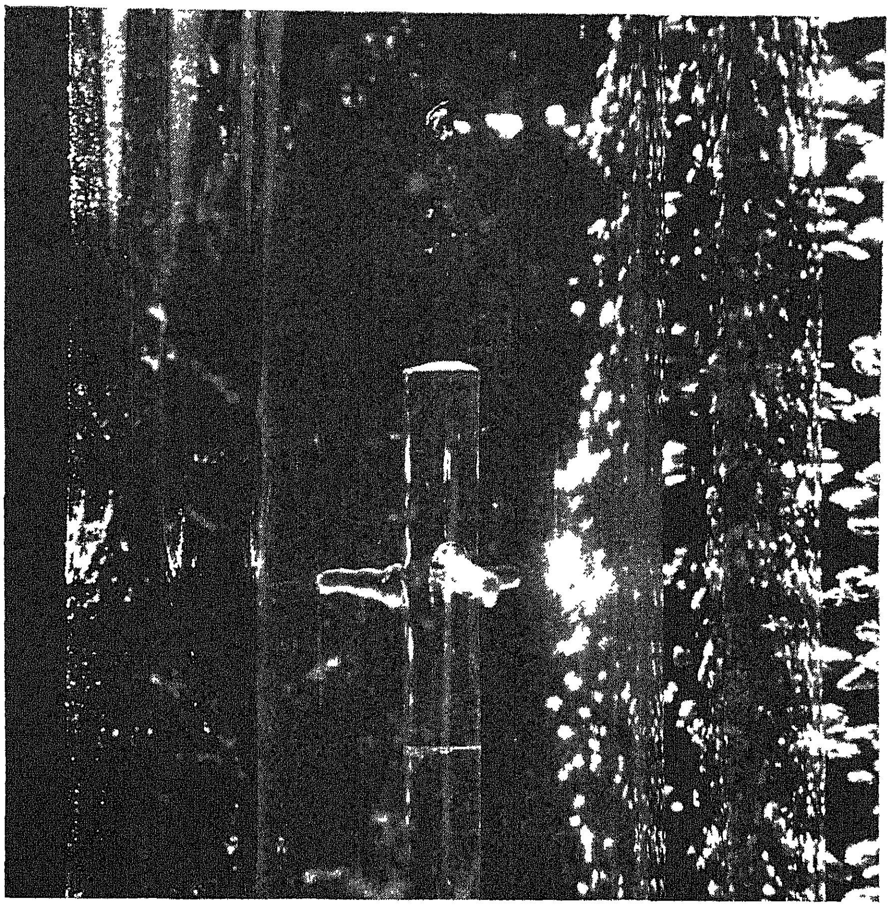
sure of the helium drops so low that there is as much chance of an atom escaping into the space above the surface as there would be of a piece of iron boiling out of the structure of a building at room temperature. Air or anything else that possibly leaked into the dewar would freeze solid. In the space just above helium close to absolute zero, there is just about absolute emptiness

In this cold, still realm, physicists are checking the basic concepts of thermodynamics that were set forth in the days when physics could only deal with the thermal chaos. They are giving a more direct physical meaning, in terms of atoms and their electrons and nuclei, to such statistically derived words as heat, entropy and temperature. They may emerge with a new definition and a more accurate localization of "absolute zero."

Already there are some who are not satisfied with the prospect of reaching .001 degrees K., which is the most to be expected from regimenting and relaxing the spin of electrons. They are looking ahead to using the last conceivable resource: the magnetism of atomic nuclei. This, according to the theoreticians, offers the possibility of temperatures that will not exceed absolute zero by more than a millionth of a degree.

To this writer, the laboratory that best represents the varied prospects, abstruse and practical, of cryogenic research, is that of Ohio State University. For the attainment of extremely low temperatures by electron demagnetization, a current-carrying coil is used to set up a magnetic field of 4,000 gauss. The coil is cooled by liquid nitrogen. This does not attain superconductivity, for which liquid-helium temperatures would be needed, but it does exploit the normal drop of electrical resistance with reduced temperature. Thus the lowest temperatures of an earlier era of cryogenic research abet the attainment of new depths; cryogenics lowers itself by its bootstraps. When workers in the field are asked if there is any possibility of ever using real superconductivity for the powerful electromagnets of cryogenics and nuclear physics, they will admit that it does not seem practical. But after a few moments meditation they are likely to remark: "Well, at Ohio State, you know, they're using liquid nitrogen. . . ."

Harry M. Davis was the author of Radio Waves and Matter *and* Mathematical Machines, *which appeared in past issues of this magazine. A week after he had completed the present article, Davis was drowned in a swimming accident at Biloxi, Miss. He was one of the rare professional journalists whose reporting of science was admired by scientists. His death is a grievous loss to the journalism of science.*



FOUNTAIN EFFECT of liquid helium is photographed in the laboratory of Arthur D. Little, Inc. Glass tube in center is inside Dewar flask containing liquid helium. Top of fountain is just visible near the top of picture.

CREEPING FILM appears as a tiny luminous drop on the curved bottom of a vessel filled with liquid helium. The liquid has climbed up the inside of the vessel and down the outside. It climbs into an empty vessel in same manner.

Ancient Slavery

In Greece and Rome the institution took many interesting forms that have been obscured by the more recent memory of slavery in the U. S.

by William Linn Westermann

GREEK CUP of the Sixth Century B. C. depicts the contemporary practice of slavery. Under the direction of the Spartan King Arkesilas (*left*), both slaves and freedmen weigh and bale goods meant for the export trade.

THE institution of slavery has always been integral to the economic system of which it is a part, serving to supply some of the labor needed in that particular system. From the standpoint of the users of slave labor it has always had the important advantage of giving them a much greater control over the activities of the persons working for them as slaves than over free laborers working for them under contractual arrangements. Their control over their slaves was theoretically complete, covering the lives, activities and personalities of the enslaved. Legally slaves were regarded as goods, like machines that a factory owner might buy or the draft animals that a farmer might employ. In Roman legal terminology, correspondingly, a slave was classified not as a person but as a *res*, a thing.

In the legislation set up to control slave systems the history of human enslavement can be traced back to the earliest periods of written laws known to us, in Egypt, in Babylonia, and in the Mediterranean areas that later fell under Greek and Roman control. This carries the system some 5,000 years back from the present day. One glance at the reports on slavery made to the League of Nations from 1923 onward is enough to prove that human enslavement is still a going concern. Despite the efforts of the major European countries to abolish the traffic in slaves and the entire practice of enslavement, the sale, transport and use of slaves persist in the world.

In Siam the slave system was abolished as late as 1905. In China a decree was promulgated in 1909 officially prohibiting the practice. In 1923 slavery still existed in Abyssinia. We of the U.S., after countenancing 85 years of Negro enslavement, are in no position to adopt an attitude of moral superiority. We must also remember that our African ward Liberia, in its reply to a League of Nations inquiry in 1924, acknowledged that slavery was still practiced by some Liberian tribes. To their reply they added the hope of its complete abolition in the near future.

On October 22, 1948, at the Paris meeting of the General Assembly of the United Nations, the Belgians presented a resolution asking that a committee be appointed to study the problems of slavery as it still exists and to report to the Economic and Social Council of the UN. The genesis of the resolution lay in the patent fact that remnants of the slave system, though scattered, are still to be found in our world. The long book of 5,000 years of human enslavement is not yet closed.

Slavery as it developed in the Western Hemisphere has given rise to a marked popular misunderstanding of the history of the institution. This misunderstanding has surcharged our approach to slavery with emotionalism and has distorted its meaning in the long perspective of history. The distortion has arisen from the fact that in both the northern and the southern continents of our hemisphere, the Indians were unable to endure either the heat of labor in the tropics or the restrictions upon their liberties that resulted from reduction to slavery. In Africa, however, the enslavement of members of one tribe by another tribe had long been customary. The use of African slaves was also established in Portugal and Spain. Because of the labor demand in the Western Hemisphere and because of the fact that Portugal and Spain were already being supplied with African slaves by Portuguese traders, the early settlers of the Americas looked to the continent of Africa for slave labor There the labor supplied them was already inured to hot and moist climatic conditions, and, for this reason, was peculiarly adapted to their needs

This conjunction of demand and supply might be regarded as a historical accident. Yet it is this coincidence of conditions that has made us think of human slavery so consistently in terms of the Negro alone. The three and a half centuries of almost exclusive Negro slavery which has been known to us, however, is no more than a brief chapter in 50 centuries of the enslavement of man by man.

During the past century and a half the civilized world has rightly come to regard slavery as a degradation of human values and as an economic and social stupidity. For 3,000 years of pre-Christian history, on the other hand, it was countenanced without any ethical misgivings that can be detected in slave legislation, whether old Babylonian, old Hittite, Assyrian, or the Hebrew of the Old Testament. It is true that these pre-Greek peoples did not sanction the enslavement of a Babylonian or an Assyrian by a fellow Babylonian or a fellow Assyrian, and that the ancient Hebrews permitted only a six-year bondage of one Hebrew to another. This attitude can be explained as a consequence of the religious nationalism characteristic of these pre-Greek civilizations It cannot be ascribed to a sense of moral horror against enslavement itself.

With the Greeks the slave institution developed two features that distinguished it from the form known among the pre-Greek cultures of southwestern Asia. The first was that Greek nationals could become slaves of other Greeks. In the dramas of Euripides slaves, both Greek and non-Greek, appear frequently as pathetic figures who complain bitterly about their lot. A second departure of the Greek type of slavery from that of the old Oriental cultures lay in the fact that the Greek gods were not slaveowners. The temple organizations owned slaves, but the gods did not

With few exceptions, such as the *Works and Days* of Hesiod and the books of the New Testament, the literature of antiquity is aristocratic in tone and point of view, reflecting the attitude of people of higher social status. Thus the workers of antiquity, whether free or enslaved, seldom speak to us with their own voices. Insofar as we can penetrate into the thinking and reactions of a freed, or manumitted, slave in the Greek city-state, it appears that he was readily absorbed into a noncitizen group called the metic, that is, the "coresident," class.

In a satire written by Petronius, the "Arbiter of Elegancies" under the Emperor Nero, one of the freedman guests at a hilarious banquet given by Trimalchio, a preposterously wealthy former slave, makes an illuminating statement He says that he was a slave for 40 years, but no one cares whether he was previously a slave or a free man. The case of Cicero's secretary Tiro, a slave whom Cicero later freed, may not be entirely typical so far as the intellectual sympathy and genuine friendship between the two are concerned. Nevertheless it illustrates the possibilities of the master-slave relationship in Rome, where the lines between the slave and free classes were more strictly drawn than in the Greek world. In 50 B C , when Tiro was sick, Cicero wrote him from the island of Lucas: "Your services to me are beyond numbering: at home, in the Forum, in the city, in my province, in public life, in my private affairs, in my studies, in my literary compositions. You will have surpassed all these services to me if I find you well, as I hope to do, when I return."

THE fundamental problem of any slave system is always the same. The details of the problem differ, and the means of adapting the institution to meet these differences call forth different responses. There are differences in the source of the slave supply, in the methods by which the slaves are obtained, in the existence of free labor at a particular time and place; in the type of employment. A primary error in studying and writing about ancient slavery has been the neglect of these differences. Historians have treated the institution as one thing, "ancient slavery," throughout the 4,000 years of its constant presence in antiquity, but even between the Greek and the Roman forms of enslavement basic differences must be established.

The Greek city-states were small governmental organisms under the direct, democratic rule of a limited and privileged group of citizens. In these microcosmic states the dominant use of slaves was in urban handicrafts. In the western Mediterranean countries, including Roman Italy down to the end of the Second Century B.C., slaves were employed for the greater part upon plantations called latifundia. This system produced two things that have served to prejudice our thinking against the entire system of slavery in antiquity. These were the

great slave revolts that occurred during the Second and First Centuries B.C. in Sicily and Italy, and the book *On Agriculture* written by the elder Cato.

In Greece the system was by no means so unfeeling as in Roman Italy and Sicily. In their living arrangements the slaves of Athens had a considerable degree of personal freedom. In the Fifth and Fourth Centuries there was a class of slaves in Athens who were called "those who live apart," meaning apart from their owners. They were also called "pay earners." These were workers who were rented out by their masters at so much a day. The expectation was that they would bring a net profit of one obol per day. The average purchase price of a fairly good slave was from 300 to 400 drachmas. This would give an annual profit on the slave of 15 to 20 per cent, if he were leased out for the entire year and put in 350 days at work.

Evidence from lists of manumitted slaves which were inscribed upon stone in Athens in about 330 B C. gives us some knowledge of the occupations at which these slave workers were employed. The largest group consisted of women in the weaving industry. Others were porters, who carried their deliveries throughout the city of Athens. Those who operated handicraft shops might own enough slaves to run their shops with their own workmen. A well-known example of this is the two handicraft shops that Demosthenes, the Athenian orator and politician, received through the will of his father Along with a bed-frame shop he inherited 20 slaves. With a cutlery shop came 32 or 33 slave artisans.

Another distinguishing feature of slavery in the Greek city-state was the use of state-owned slaves in the police force and other public services. In Athens the state bought foreign slaves, chiefly Thracians, for police work (and permitted them to use their native Thracian dress as their uniform). This single fact differentiates the Greek attitude toward slavery from that of the Romans. To the Romans the possibility of being arrested by a slave would have been as unthinkable as it would have been under the slave system in our own country before the Civil War.

FROM the stone walls of the sacred precinct of Apollo at Delphi we have records of a thousand manumissions of slaves, dating from 200 B.C. to about 75 A.D. These manumissions were carried out by an interesting religious process It is evident that the slaves were permitted to save money by their work in order to buy themselves out of enslavement. This was a recognized social and economic arrangement, though legally slaves could have no money of their own.

Some sharp legal minds, presumably among the priests of Apollo of about 200 B.C., devised a system of circumventing these difficulties. The slave could entrust to the god Apollo his money, his person and his hope of freedom. If the god accepted the trust, the slave automatically became a freedman. For to the god all of his worshippers were alike and of one status.

One of these entrustment sales which is dated late in the Second Century B.C. states. "Athambos has sold to Apollo, the Pythian god, a woman slave whose name is Harmodica, by race from the town of Elatia, for six minas of silver; and he has received the total price, just as Harmodica entrusted to the god this purchase, entrusting it to the god on the consideration that she is to be free and not subject to seizure by anybody for all time. She is to do whatever she wishes, and is to go to whomsoever she may wish."

The instrument of sale goes on to state: "If anyone should touch Harmodica for her enslavement, let the seller, Athambos . . . guarantee for her the sale to the god. Likewise, if any person attempt to re-enslave her, any chance passer-by, without any penalty and without being subject to any court action or fine, is empowered to release Harmodica as being a free woman." On analysis it becomes clear that this legal form contains a description of what freedom meant to the Greek mind Freedom was composed of four elements that a free man has and a slave has not. These "four freedoms" show a much greater precision than our own generalities of today, at least as they are expressed in the Atlantic Charter. They lie in the assertion that the woman is to be free, that she is not to be subject to illegal seizure, that she is to have the right to work at whatever she wishes, and that she may go wherever she wishes. The first of these rights is political status, the second is the right of habeas corpus, the third is the economic right to dispose of her working ability under a free labor contract, the fourth is the right to freedom of movement.

In the countries stretching along the Mediterranean coast from the Adriatic Sea westward, the aspect that the slave system presented down to 100 B.C. was much grimmer than in the Oriental and Greek lands at the eastern end of the Mediterranean. The differences in the brutality accorded to the slave arose primarily from the dissimilarity of slave occupations in the two regions and from the stern morality of the Roman leaders. Cato the Elder of the Second Century B.C. tried to embody, and thought that he represented, the old Roman *mores*.

If a slave waiter made a slip in serving dinner, or if a slave cook spoiled anything in the preparation of the dinner, Cato would use a leather strap in punishing him. If a slave committed any technical crime, Cato conducted a formal trial If the slave were condemned, Cato had him put to death in the presence of his fellow slaves. In Cato's book about agriculture, the rations to be given out to the slaves were obviously adjusted to their work. More bread was to be given them at the time of heavy field work, and less bread in periods of lighter work The rations he advocated without a doubt compared favorably with those given to Roman soldiers, but the purpose, so far as Cato was concerned, was pure efficiency.

It is apparent from Cato's discussion of agriculture that the number of slaves employed on a large plantation in Italy was not so great as historians have sometimes thought. The total to be used in an olive orchard of 150 acres, according to Cato's advice, should consist of a nucleus of only 12 slaves. This number included the overseer and his wife, both of whom were slaves.

The following cold-blooded statement that Cato makes in his book seems to be typical, for his period and for men of his kind, of the treatment accorded slaves by the Roman landowners. "The plantation owner," he said, "should auction off old work-oxen, blemished cattle, the wool, the skins, the worn-out iron tools, the aged and diseased slaves, and everything else that he does not need " Writing 250 years later Plutarch, the Boeotian gentleman farmer and moralist, condemns Cato bitterly for this attitude. In his *Life of the Elder Cato* Plutarch says: "For my part I regard his treatment of his slaves like beasts of burden, using them to the uttermost and then when they were old driving them off and selling them, as a mark of a very mean nature, which recognizes no tie between men except necessity. I certainly would not sell even an ox that had worked for me just because he was old, much less an elderly man, removing him from his habitual place and customary life as if it were from his native land, for a paltry price, useless as he is to those who sell him and as he will be also to those who buy him."

An unusual feature of slavery as it developed under early Roman conditions gave it one element of superiority over the Greek system. This arose out of the greater flexibility of the Roman idea of citizenship, as compared with the exclusiveness of the Greek polities toward their citizen privileges. If a slave owned by a Roman citizen were freed by his Roman master, after his manumission he became a Roman citizen. This could not occur under the Greek system.

WITHIN the Roman slave institution itself a notable change occurred in the treatment of slaves in the two and a half centuries that separate the quotations cited from Cato the Elder and Plutarch. This change was an increased mildness in the treatment of slaves that

finds expression in the Roman legislation of the First Century A.D. The laws passed by the emperors of this century include punishments of slaveowners for abandoning old slaves. This change of attitude has sometimes been ascribed to the spread of the Stoic doctrine through the West in the First Century B.C., and to the acceptance of the equalitarian teaching that Stoicism advocated. It came too late, however, to be explained as a Stoic influence upon Roman legislation, and it came too early to be an outcome of Christianity and its teachings. The Christian teaching, as a matter of fact, accepted the going institution of slavery, as did every other religious movement of the time This is shown by the advice given by St. Paul to the converts in Corinth, which is found in the first letter to the Corinthians.

"Everyone has his own vocation in which he has been called; let him keep to it. Hast thou been called as a slave? Do not let it trouble thee; and if thou hast the means to become free, make all the more use of thy opportunity. If a slave is called to enter Christ's service, he is Christ's freedman; just as the free man, when he is called, becomes the slave of Christ. A price was paid to redeem you; do not enslave yourselves to human masters. Each of you is to remain, brethren, in the condition in which he was called."

A sounder explanation for the change in the Roman attitude toward slavery may be found in the industrializing of slavery in the West, that is, in the increased use of slaves in handicrafts. This brought about a concentration of slaves in towns and cities and the drawing together of the poor workmen of free status with their fellow slave workmen. Viewed in this light it would be an effect of the urbanizing of slave employment. Christianity, even when it became the sole religion tolerated in the Mediterranean area, did not try, nor did it express a desire, to abolish slavery. It took over the institution, but not all of its implications. It is in this internal sense, the equalitarianism within the group that was taught by St. Paul and the contemporary Roman Stoic Seneca, that Stoicism and Christianity bettered the condition of slaves. This was true of the groups that adopted Stoicism, and later, in much greater numbers, the Christian faith. Once accepted into the Christian group the slaves who were "called" were equalized in spirit with the free. For the Christians the Day of Judgment was close at hand; and the kingdom into which they were to enter was the Kingdom of God, without gradations of caste or status.

William Linn Westermann is professor emeritus of history at Columbia University.

ASSYRIAN BAS-RELIEF of Seventh Century B.C. shows procession of prisoners driven by soldiers (*top*). Assyrians did not enslave one another.

THE SOCIAL AMOEBAE

The independent cells of Dictyostelium periodically gather into an organism of many cells. The study of this peculiar phenomenon is a felicitous example of the scientific method

by John Tyler Bonner

FOR some reason that has never been entirely clear to me, few people have heard of the *Acrasiales,* or amoeboid slime molds. It is less surprising, since they are such strange organisms, that those who have heard of them are often tempted to become philosophical. There is the case of a German scientist who used them to prove the existence of a vital force in living organisms. There is also the case of a well-known American physiologist who likened them to human society. Our aim here is more modest We shall ask no more of the amoeboid slime molds than that they shed light on themselves.

The amoeboid slime molds look to the naked eye very much like the common bread mold *Mucor.* There is no way of knowing how long they were mistaken for *Mucor,* but the first clear-cut case of such an error was that of the 19th-century Belgian botanist E. Coemans It is Coemans, in fact, who is credited with first describing the *Acrasiales* in this fashion. It was left to a German named Oskar Brefeld and a Frenchman named M. van Tieghem to discover the peculiar nature of these organisms between 1869 and 1880. It was not, finally, until the classic monograph of the American botanist Edgar Olive in 1902 that the whole group was clearly defined. The most recent historical event is the discovery by Kenneth B. Raper of the U. S. Department of Agriculture of a new species, *Dictyostelium discoideum* It is this species that is especially suited for experimental studies.

The spore may be used as a convenient starting place to describe the life cycle of Dictyostelium. The spore is in no way connected with fertilization, for so far as is known there is no sexuality in these forms. It is shaped like the pharmacist's gelatin capsule, and if it is sown in a suitably warm and humid environment, it will germinate by splitting down the side and hatching one tiny amoeba.

One of the most remarkable things about this amoeba is that it is no different from any other amoeba. It has the characteristic fluctuating, amorphous shape; it feeds by engulfing bacteria in the usual way; it divides regularly by binary fission. In every way it is a very ordinary amoeba. When enough of these separate and independent amoebae are concentrated, however, a curious thing happens. As if in response to a signal, they cease to ignore one another and rush toward central collection points. The shape of the amoebae, though highly irregular and constantly changing, is usually approximately round When the amoebae come together they stretch into pencil shapes and rush inward with unerring accuracy.

When the amoebae have come together, they form a mass shaped like a sausage. This may be from .1 to two millimeters long, depending on how many amoebae gather at a particular collection point The sausage of amoebae then proceeds to crawl across the surface of its medium! As the sausage moves, it exudes slime, which is left behind as a collapsed cylinder rather like a sausage casing.

That these cells act as a body rather than individually is best illustrated by the fact that the sausage will crawl toward light. The actual locomotion, however, appears to be a contribution of each individual amoeba. In special microscopic preparations it can be seen that the amoebae are all in motion and that they continuously extend their pseudopods, or "false feet." The point is that in some way this movement of the independent amoebae is coordinated so that the mass of cells moves as a whole.

Depending on moisture and temperature and probably to some extent on light, the migration period may last a day or more. Sometimes it is by-passed completely. In either case the cell mass eventually assumes an upright position in preparation for what is known as the culmination stage.

At the beginning of the culmination stage the aggregate of amoebae looks like one of those small blobs of icing a baker puts around the edge of a birthday cake—it is a rounded mass with a pointed tip thrust upward. When thin slices of the mass are examined under the microscope, it may be seen that in the center of the tip there are groups of cells that rapidly become large and swollen, as though they were gorged with water. This swollen condition then spreads downward like a disease to the base of the mass. The swollen cells become encased in a firm cylindrical sheath so that our blob of soft wet icing now has a rigid core. The unchanged amoebae which surround the core begin to rise into the air. As they do so the uppermost amoebae are drawn to the top of the rod, where they immediately begin to swell as though they too had caught the disease. Together these two processes go on, and the rod, or stalk, as it may now be called, becomes increasingly longer. This elongation is apparently capable of lifting a ball of other amoebae to form a structure shaped like a minute hatpin. This hatpin, which is usually from one to three millimeters high, is the final fruiting body.

All the amoebae except those in the stalk ultimately become spore cells. Each amoeba in the rounded mass assumes the shape of a pill and is encased in a hard, resistant capsule. Thus two types of cells have arisen from our amoebae. the enlarged cells of the stalk, and the small spore capsules. Recent observations have revealed that normally some 14 per cent of all the cells are stalk cells. The remaining 86 per cent are spores.

NOW we may reflect upon a few significant points. We have in Dictyostelium an organism that first exists as single, separate amoebae which subsequently aggregate to form cell masses so unified and so coordinated that they act as an individual. At a particular period in their life history an imaginary knife divides 14 per cent of the cells into stalk cells and 86 per cent into spores We are confronted with two questions. One is. How can it be that these cells are brought together? The other is. How is it that once they come together they are coordinated? The first of these questions is rather an elementary one, and we shall discuss it. If we knew the answer to the second, we would have the solution to one of the main problems in biology.

In 1900 the scientists who studied these slime molds were generally agreed that the amoebae gathered at central collection points as the result of chemotaxis. By this they meant that a chemical substance given off by the central mass attracted the amoebae in much the same way as the smell of a carcass attracts a jackal. There was no real evidence for

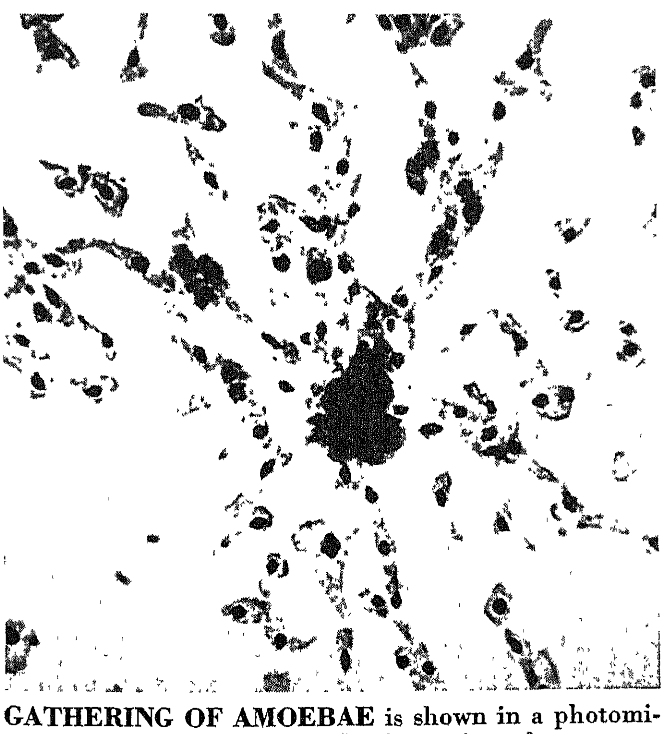
such an idea, it only "looked" that way It was really just as reasonable to suggest that the process might take place by some clotting reaction similar to that which occurs among blood cells. The process could also be governed by an electrical field, or by a magnetic field, or by some sort of ray, or by some kind of contracting molecular film.

Actually the agglutination hypothesis—the proposal that the cells would stick together and form clots—was the least likely. In 1942 Ernest Runyon of Agnes Scott College performed an ingenious experiment that gave it a final blow. He placed a central mass of Dictyostelium cells on one side of a piece of cellophane, which is semi-permeable When individual amoebae were placed on the other side, the amoebae were attracted to the central mass right through the cellophane. The amoebae could not penetrate the cellophane, but they collected at the point nearest the central mass on the opposite side of it So here there was no question of the cells touching, and agglutination forces can only operate after cells have come into contact with one another. They attracted one another from a distance.

I WAS fortunate enough to find a technique of handling the amoebae in such a way that they would aggregate on the bottom of a glass dish filled with water. If in such a preparation you remove a central mass of cells and place it quite a distance from the stream of cells that had been leading to it, three to five minutes afterward each cell in the stream will separate from its neighbors and make a beeline to the central mass at its new location. In this way one can demonstrate that the amoebae will be attracted to masses that are half a millimeter away, which is equivalent to about 60 amoebae diameters.

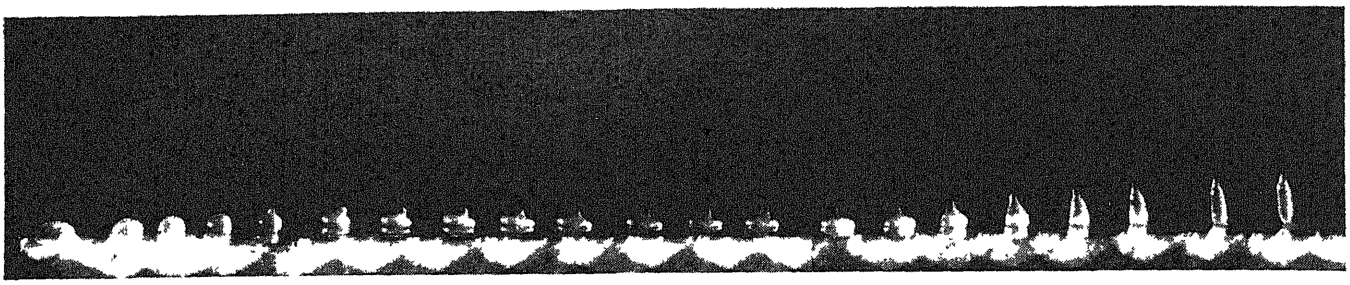
The possibility that electricity or magnetism was involved was tested in a number of ways First the amoebae were placed in an electric field and subjected to a variety of current densities. It was found that, depending on the strength of the current, there was either no effect at all or the amoebae were killed. This is surprising considering the classic experiment of the German physiologist Max Verworn, who showed that ordinary amoebae streamed toward the negative pole of an electric field. In fact, I was able to repeat this easy experiment in the same vessels I used for the Dictyostelium amoebae. A few haphazard experiments were performed by placing magnets near the amoebae, and, as expected, no effects whatever were observed. The experiment that proved most rewarding was suggested by Paul Weiss of the University of Chicago. It was to use a thin piece of the nontoxic metal tantalum in precisely the same way that Runyon had used cellophane. Whereas individual amoebae had been attracted to a central mass through cellophane, nothing of the kind occurred with tantalum. The amoebae merely gathered independently on both sides of the metal This demonstrated that neither magnetism nor electricity influenced the amoebae. If these forces had been operating, the metal might, by some sort of short circuit, have prevented aggregation from occurring at all. And if they had been operating when aggregation did occur, there should have been some effect through the tantalum, since it is probably an even better conductor than cellophane.

It was conceivable that the amoebae are guided to the central mass by a ray just as ships are guided to a harbor by a beacon. For many years biologists have wrestled with the concept of the so-called mitogenetic rays. A Russian scientist named Alexander Gurwitsch believed he possessed evidence that actively developing organisms emitted rays which controlled and "organized" their development. His work generated a great mass of controversy, and today it is generally accepted that such rays have never been positively demonstrated. Fortunately I was able to avoid the storm by showing that no kind of ray is involved in the aggregation of Dictyostelium. This was done by an experiment in which a thin glass shelf was suspended under water. A central mass of cells, which for convenience may be called a center, was placed on the upper side, and separate amoebae on the under side. After a time the separate amoebae all rounded the edge to the upper side and streamed in to the center If the center had been a beacon emitting rays, the rays could either have penetrated the glass or not. If they had penetrated, one would have expected the same result as that obtained with Runyon's cellophane. The amoebae would merely have gathered on the nearest point at the other side of the glass. If the rays had not passed through the glass, one would have expected the individual amoebae to be completely unaffected by the center. Since the amoebae were attracted around a sharp corner, and since no ray can bend around a corner, we can say that rays, mitogenetic or otherwise, do not play a



GATHERING OF AMOEBAE is shown in a photomicrograph of early stage in the formation of aggregate.

CENTRAL MASS GROWS as more amoebae stream into it. Later the mass begins to move as one organism.



CULMINATION STAGE of Dictyostelium is attained in the photographs at the top and bottom of this page. At the left above is the migrating aggregate of amoebae. At the right the aggregate has begun to raise itself.

part in the aggregation of Dictyostelium

Another possibility was that some kind of a film along the glass-water boundary helped orient the amoebae. To test this hypothesis two submerged glass shelves were placed side by side, leaving a narrow gap between them. A center was placed atop one of the plates and separate amoebae atop the other. Again all the separate amoebae streamed to the edge of the shelf nearest the center and, since the amoebae could not bridge the gap, they formed a center right at the edge. This proved that the attraction can occur across a region where there is no glass-water interface. It is known, however, that the amoebae need an interface for locomotion. The amoebae actually appear eager to cross the gap, for one can see them pawing the air with their "false feet" in a very frustrated manner. If the two glass shelves are pushed together so that the gap is only one amoeba's length, the amoebae will immediately form a hanging bridge. Then the amoebae stream in to the center, happy, we may presume, at last.

THERE are a number of other hypotheses that can be and have been tested, but among those tested there was no positive evidence. It was only in testing the chemotaxis hypothesis—the early suggestion that the center emits a chemical substance which attracts the amoebae—that some concrete evidence was finally secured.

If aggregation takes place on the bottom of a dish, and the water above the amoebae flows over them gently, as though they were lying on the bottom of a brook, only the amoebae downstream are oriented toward the center. The amoebae upstream show no interest at all in the center. This must mean that the attracting agent is capable of diffusing, for it can be washed downstream. The only two diffusing agents are heat or chemical substances. For a number of reasons which I shall not discuss here, heat can be rejected, leaving a chemical substance as the only possibility

The center, of course, does not really "attract" the amoebae in the sense of pulling them in. Presumably the chemical substance that is given off by the center is always more abundant near the center than it is farther away. Therefore the front end of the amoebae approaching the center will be surrounded by more of the substance than will the hind end. In other words, all the substance accomplishes is to orient the amoebae by stimulating the front end more than the hind end. The movement is solely that of the amoebae. The smell of carrion does not pull at the jackal, but it gives him a guide to where he may find the carcass. And the nearer he gets, the stronger the scent.

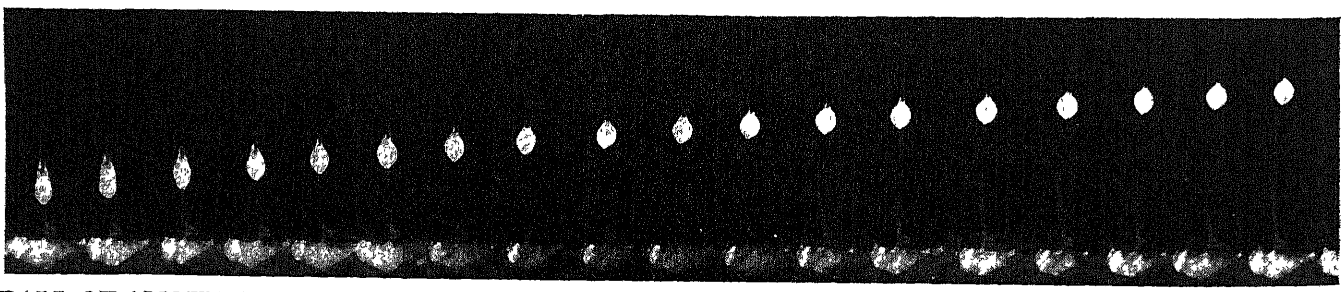
The evidence is thus extremely good for the existence of a chemical influence in the aggregation of Dictyostelium. If there were some way of isolating the substance *in vitro* we would have a proof of its existence, but so far all attempts in this direction have unhappily failed. It is suspected that the substance not only breaks down readily but that it is not stored in the organism. It appears only to be produced by the living machinery It was decided that the substance should at least be tentatively named, and after much deliberation and research I found that a witch in Edmund Spenser's *Faerie Queene* was named Acrasia, and that she attracted men and transformed them into beasts:

The faire witch here selfe now solacing
With a new lover, whom through sorceree
And witchcraft, she from farre did thither bring. . . .
More subtile web Arachne cannot spin

Since Dictyostelium is also a member of the *Acrasiales,* it was clear the substance had to be called acrasin.

Once the peculiar life history of Dictyostelium is grasped, the very first question one asks is how it arose in evolution. It is very easy to see that, in a bird, wings are of advantage to escape predators and to get food, and that in the evolution of birds there would likely be natural selection resulting in better and more efficient wings. It is harder to see why Dictyostelium is a more effective organism than common amoebae. In fact, there is always the possibility, which we will ignore, that it is not. The spores of Dictyostelium might be more resistant to adverse environmental conditions, but many common amoebae form cysts which also are resistant.

Perhaps Dictyostelium has a selective advantage in being elevated on a stalk. There are a number of reasons for believing that because the amoebae are up in the air they are hardier than they would be in the water. David Perkins of Stanford University has made another likely suggestion. This is that elevated amoebae have a better chance for distribution, especially because the spores would tend to adhere to insects brushing past them. These arguments are rather tenuous, and I will ask you merely to assume that the fruiting bodies of Dictyostelium help it survive, and to believe at least that there has been evolu-



BALL OF AMOEBAE is lifted above the surface of its medium by a slender stalk of other amoebae. Cells of the ball are principally spores. The height of the entire organism at right is approximately .4 of an inch.

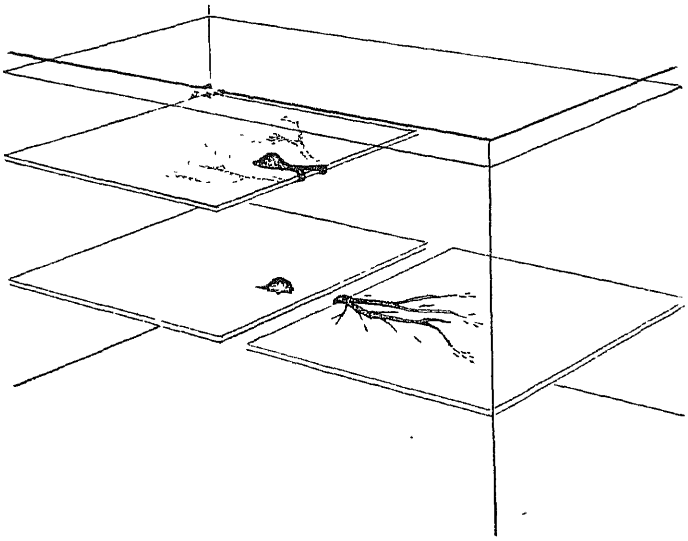
tion from the common amoeba to Dictyostelium.

There is some support for this latter assumption in the intermediate forms between common amoebae and Dictyostelium. There are some forms that simply pile up in shapeless mountains of amoebae These do not differentiate into stalk and spore. There are some that have a very crude resemblance to Dictyostelium One might just as well say that these forms represent an evolution in the reverse direction from Dictyostelium to a common amoeba. All I can ask is that you assume somewhat arbitrarily that this is not so

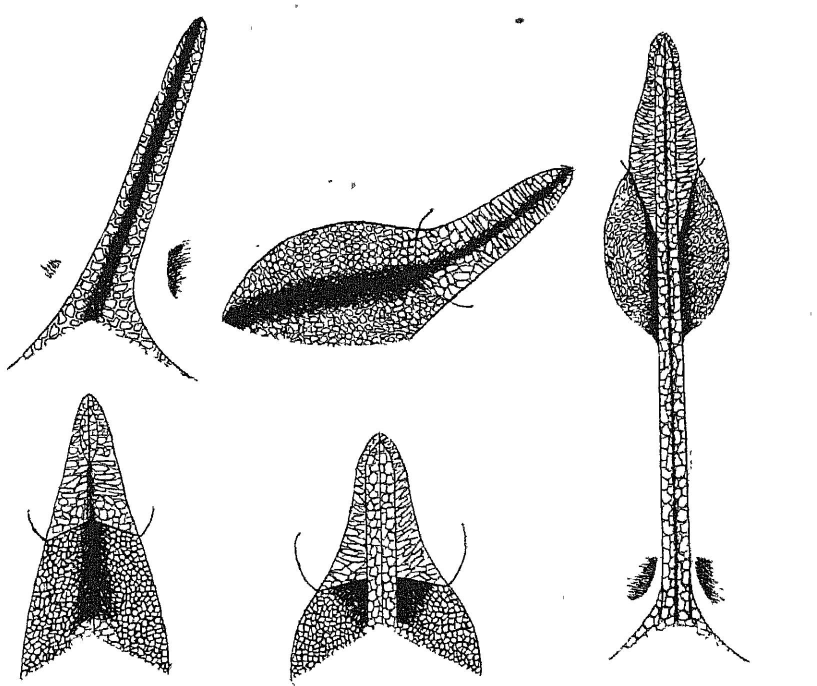
IN a recent article John R. Baker of Oxford University has noted the fact that among primitive green organisms there are more intermediates between one-celled forms and true multicellular forms than there are among primitive colorless, particle-feeding organisms. The difference is rather marvelously explained by Dr. Baker, who points out that the green cells are all photosynthetic, that is, they make their own food with the help of water, carbon dioxide and the radiant energy of the sun. Therefore they do not need any special organ for obtaining food. Any cell that eats particulate matter, however, needs a special feeding apparatus. So if you have an organism consisting of a group of adhering cells, and if it is photosynthetic, there is no mechanical feeding problem. A group of particle-feeding cells, however, must adopt a new method of feeding. This involves a very large and difficult evolutionary step. The question to examine is whether or not there is any way in which colorless, non-photosynthetic cells could circumvent this obstacle rather than tackle it head on, as have the sponges, the coelenterates and our main line of animal evolution.

It is clear that Dictyostelium, by the use of its acrasin, has found a way. All feeding and growth is accomplished by single cells that require no new method of feeding The aggregation of the cells, which we now explain by the action of acrasin, takes place after all the cells have completed their feeding. This produces a relatively simple, non-feeding, multicellular structure that raises the spore into a presumably advantageous aerial position. Acrasin, partly sired by a witch, is alone responsible for this artful dodge. It has, however, turned out to be a blind alley in evolution reaching little further than Dictyostelium itself. Surely the price of this sly ruse had to be paid somehow

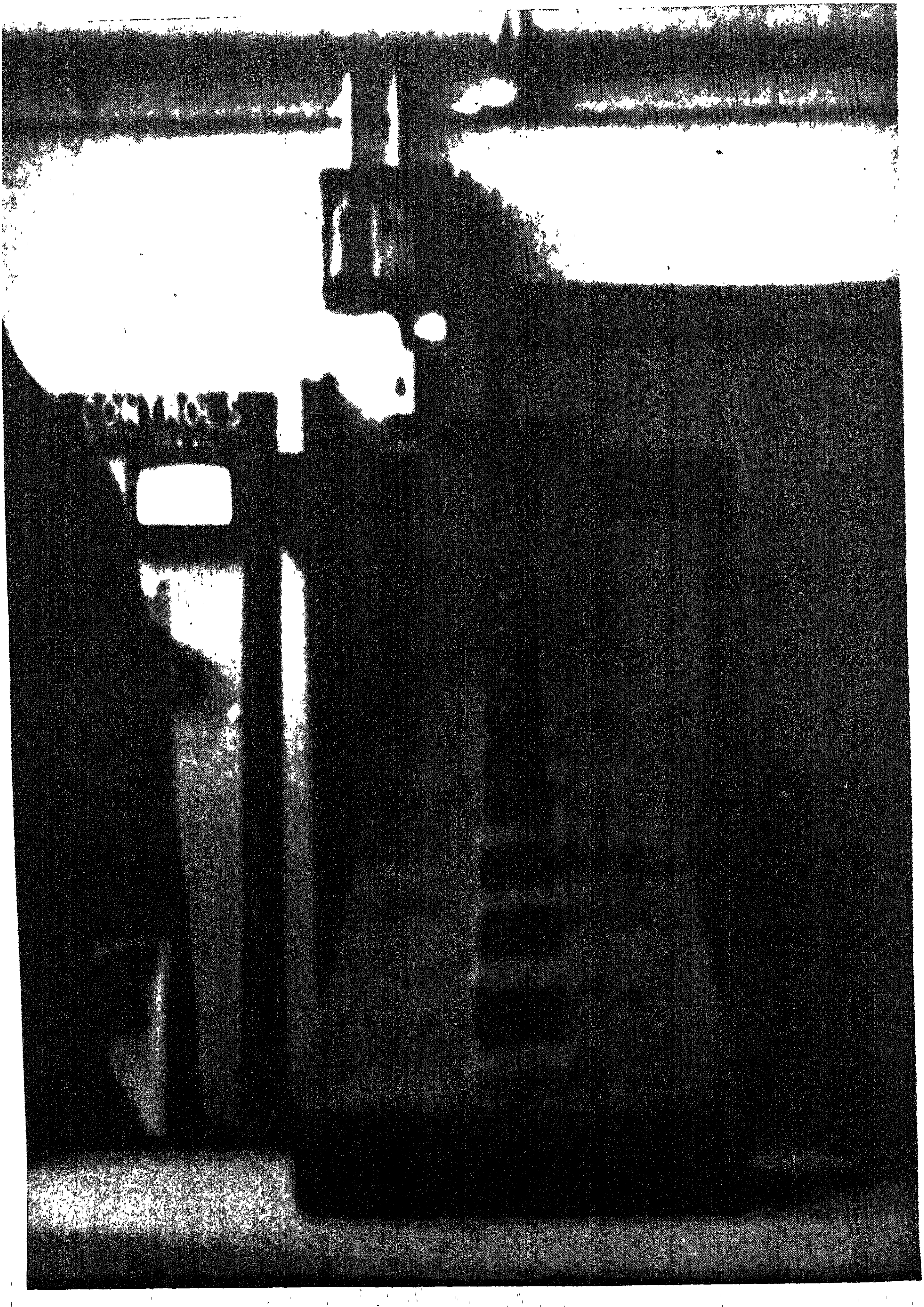
John Tyler Bonner is assistant professor of biology at Princeton University.



TWO EXPERIMENTS performed under water elucidated the mechanism by which amoebae are attracted to a central point. When a central mass is placed on a shelf (*top*), amoebae below shelf stream around edge. When mass and amoebae are separated by a gap (*bottom*), amoebae try to span it.



MULTICELLULAR STRUCTURE of Dictyostelium is shown in five stages. Drawing at upper left shows end of aggregation. Drawing at upper center shows formation of pre-spore cells. Drawings at lower left and center show formation of stalk cells. Drawing at right shows stalk bearing spores aloft.



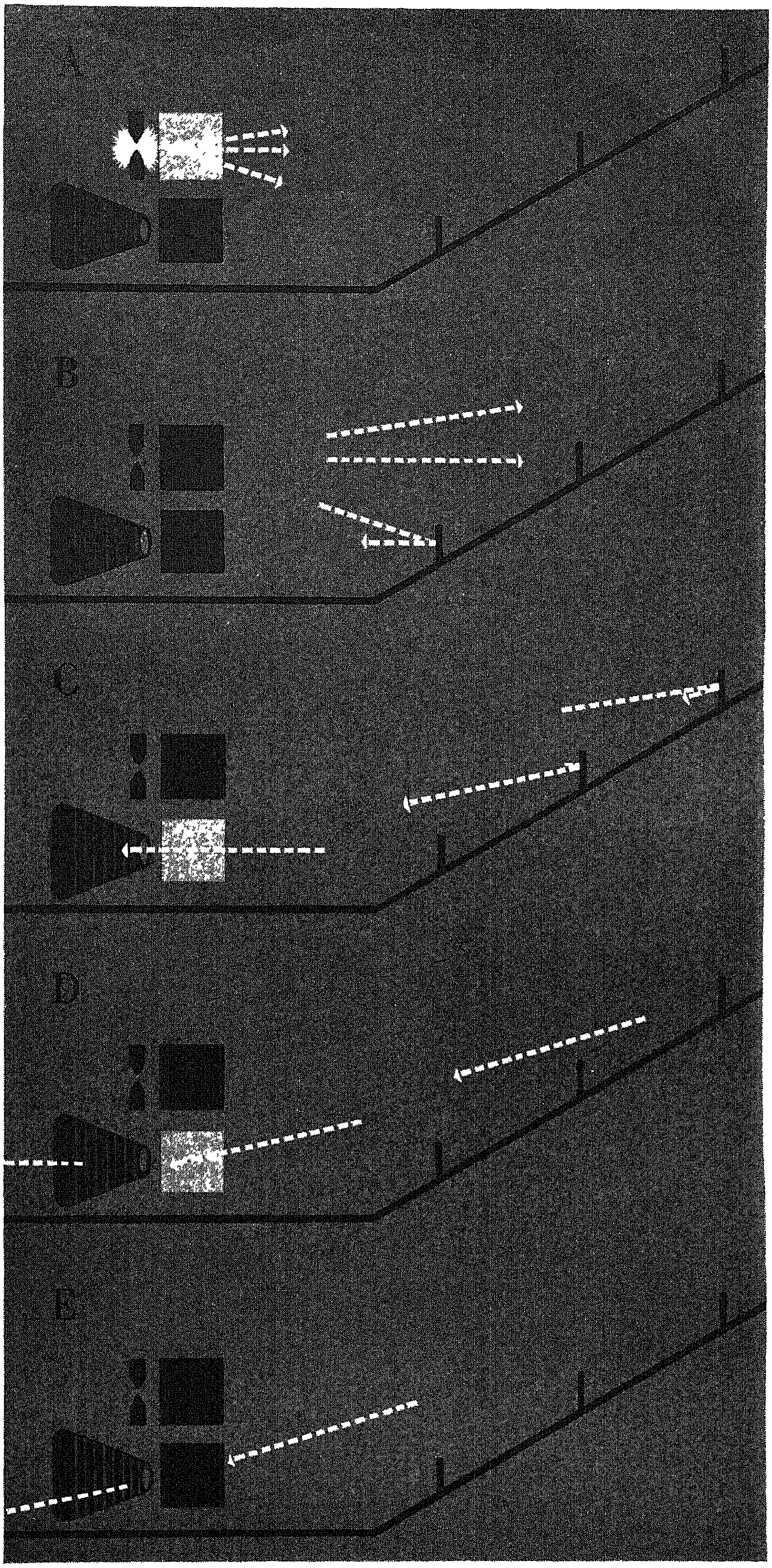
Trapped Light

Zarem camera freezes reflections of a beam of light as it speeds away from the shutter

THE seven small spots in the center of the picture on the opposite page are the reflections of a beam of light caught in mid-passage. The spots are reflected from a series of mirrors set a foot apart on an inclined platform. On a line with the mirrors is a new camera capable of making a photographic exposure lasting only .01 microsecond, or one hundred-millionth of a second.

The principal feature of the camera, which was developed by A. M. Zarem, director of the Los Angeles division of the Stanford Research Institute, is the Kerr cell. This device is made up of two flat electrodes placed in a transparent tank of nitrobenzene. Two polarizing filters may then be placed on opposite sides of the tank, crossed in such a way that no light can pass through them. When an electric field is imposed upon the nitrobenzene, it becomes birefringent, *i.e.*, the polarization of light passing through it is altered so that it can pass through the two polarizing filters. By controlling the type and duration of the electrical impulses imposed on the cell, the passage of light can be restricted to fractions of a microsecond.

The light-stopping experiment was performed by Dr. Zarem, F. R. Marshall, Norman Chase and Nicholas Saines at the U.S Naval Ordnance Testing Station in Pasadena, Calif. The purpose of the experiment was to determine the length of the shortest beam of light that can be chopped off by the Kerr cell. As shown in the diagram at the right, one Kerr cell was placed in front of a light source. After it had briefly allowed the light to pass, a second Kerr cell in front of the camera was opened. It was then able to capture the reflections of the short beam that had been passed by the first. In this way Dr. Zarem and his associates were able to show that the Kerr cell can cut off a segment of a light beam only 10 feet in length.



IN EXPERIMENT one Kerr cell was placed in front of light source. The other was placed before the camera. Open cell is indicated by gray box; closed cell by black. First cell sends a short beam of light toward the mirrors at right. Camera then records reflections from only two of the mirrors.

THE PREVENTION OF MURDER

It might have been possible in the case of Robert Irwin. Society did not accept the responsibility, but it insisted that the murderer accept the blame

by Fredric Wertham

You let him become guilty fast
And then you leave him to his pain,
For all guilt is revenged at last.
—Goethe

I SAW Robert Irwin for the first time at the end of October in 1932. He was a nice, frank-looking young man who spoke with emphasis and conviction. He had been admitted to the hospital on the 27th of October. Early that morning—at 2:20, to be precise—he had come to the surgical emergency room, having attempted to emasculate himself. In the morning Irwin was admitted to the psychiatric division, where he gave his name as Jack Adamson.

Not without difficulty, I obtained departmental permission to keep Irwin in the hospital much longer than the usual stay, in order to study his case. In the busy ward where he was confined we improvised long private interviews and psychoanalytic sessions in one of the cubicles. We kept this up till March, 1933. Eventually the pieces of his life story began to fit together.

His mother was a well-educated, college-trained woman of a very good Southern family. She studied music and at one time was acquainted with Paderewski. Members of the family were businessmen, judges, men of wealth. She herself belonged to a less well-to-do branch of the family. She was a serious-minded woman, extremely devoted to her children, and religious to the point of fanaticism.

She had four children, a baby girl who died at two of whooping cough, and three sons, one four years older and one two years younger than Robert. They all were given names with special religious associations—"the doggonedest names. We all changed them later." Robert's name was originally Fenelon Arroyo Seco Irwin. He changed it to Robert Irwin at the age of 16, after having read and greatly admired the works of Robert Ingersoll.

Before Bob was three his father deserted the family. Bob did not remember ever living under the same roof with his father, but he remembers seeing him off and on later. "He was a fine, big, handsome man." Almost up to the age of 12 Irwin idolized his father. Then his mother explained to him about his father's desertion and godless ways. After the father had left them, the family—not well off before—had a really hard time. The mother found herself with three exuberant, unruly sons. As time went on social workers, probation officers, and children's court judges became almost a part of the household.

Bob was intensely devoted to his mother. She apparently felt the same way about him, but she expressed it mostly in terms of a fanatical religious education. He had to read three chapters of the Bible every day and learn a psalm by heart every Sunday. Like red threads, the three themes of mother, religion and sex were early woven into the fabric of his life. He loved and hated all three with the full intensity of his tremendous temperament.

> EDITOR'S NOTE
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> This article is an abridged version of "Manhattan Tragedy," a chapter in the author's book *The Show of Violence*. The book was published last month by Doubleday & Company.

Bob always felt inferior to his brothers. It seems that he was always more considerate and more serious than they. When he got to the reading stage he read Plutarch's *Lives, Pilgrim's Progress,* and Shakespeare. They read detective thrillers. He thinks they were stronger than he and that other children respected them more.

He was extremely sensitive about feeling that somebody might consider him a sissy. Fighting to assert himself—that was a response that occurred over and over again in his life. It was never entirely unprovoked. But let a boy make some remark he did not like, let a taxi driver argue about the fare or a barber make what Bob considered a disrespectful remark, and off he went into a serious fist fight.

AT the age of 14 an interest entered his life that was to become a consuming passion and a conscious goal art. At first he modeled figures in butter and soap. He loved to look at pictures and collected all kinds reproductions of Greek statues, ancient heroes, beautiful and nude women. He assembled thousands of them. He never went in for obscene pictures.

Then a recurrent curse of his life supervened: unemployment. He went on his own initiative to the court of domestic relations. "The man there said, 'Why don't you learn a trade in a reformatory?' and so I asked to go to one. I would never have been a sculptor if I had not been there. The skipper there was one swell guy. I happened to remark one day that I could be a sculptor, and the very next day he brought me some clay. My career as a sculptor dates from there." By that time he was 18. He stayed in that reformatory for 15 months. His progress in art, however, was handicapped by something more serious than anything that had happened so far "that visualizing thing."

When Irwin was 15 he left grammar school to go to work as an errand boy in a wholesale house. "I remember one day there I was folding up some silk with polka dots on it and all of a sudden I leaned back against the door and my boss said, 'What's the matter?' and that's when the whole thing came to me in full force—that you have to visualize things first. Before a sculptor can make a statue he has to first make a mental statue."

This idea preoccupied him off and on and he actually practiced visualization. He would sit on the edge of the bed in his room and he would "see" in his mind

Illustrations by Ben Shahn

pictures from his collection. Once it was Napoleon after his abdication; once it was Theseus. He wanted to learn to project such pictures at will in front of him so that he could really see them. That required intense concentration.

I WENT over his sex life in some detail The influence of his fixation on his mother image was unmistakable. The first time he had intercourse was with a prostitute older than himself who realized right off that it was his first time and that he was afraid, and treated him "in a motherly way." Once he had relations with an older woman and felt ashamed afterward. "We were like mother and son. We liked each other and quarreled a lot."

In the autumn of 1931 things became too much for him. He was poor, did not make any headway with work or with art, and felt worried and depressed. He presented himself at the psychiatric city ward and was admitted. He told the doctor "I was going to kill somebody so I would be hung." When he was discharged he was sent to a convalescent home.

He stayed in the home for the period allotted by the providers of charity for the convalescence of poor people. After that he obtained a job as a waiter there. It provided food and lodging, but it was far removed from art. After he left that job he came to Manhattan. There poverty really caught up with him. He often slept in the park. He even had to go to restaurants to beg food. That was his greatest humiliation.

In this setting his emotional conflict became more and more intense, until it was unbearable, and he took the "one way out" that landed him in the psychiatric hospital where I first saw him. That was on October 27, 1932.

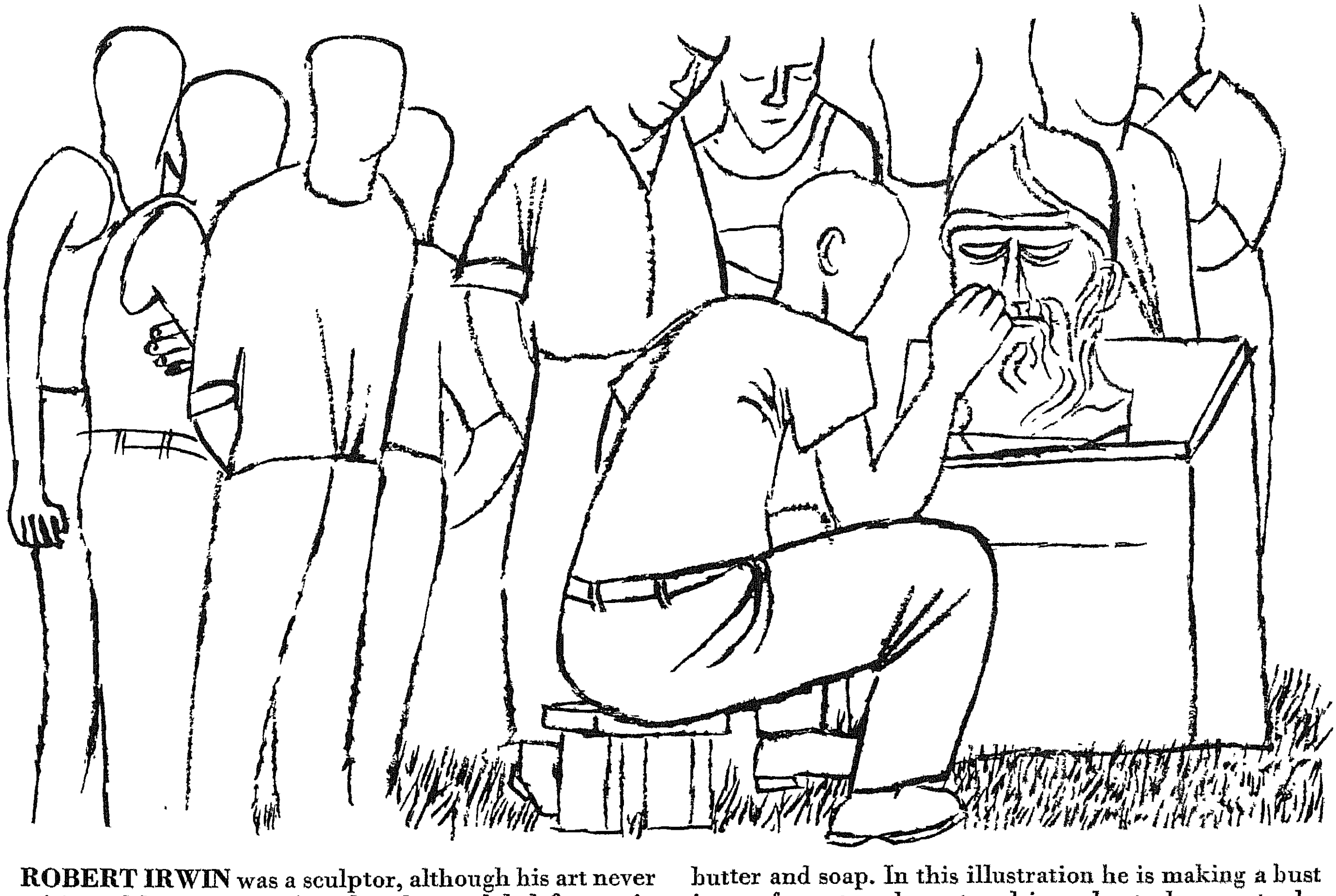
During the last period of his stay in the hospital he no longer mentioned the idea of self-emasculation. He improved under psychotherapy, but he did not recover After talking the matter over with me in great detail he consented to be committed to a state hospital. He was transferred there March 17, 1933.

The next time I saw Irwin, most unexpectedly, was on November 17, 1933, when he suddenly appeared at my home in the evening As he arrived I was just leaving for a medical meeting. He had run away from the state hospital that day. At first it was not quite clear what he wanted me to do. But after giving all his reasons and expressing his feelings, he asked me to help him get work in a convalescent place. I persuaded him that the best thing for him to do would be to go back to the state hospital.

I asked him whether he would go along with me to the meeting and let me present him to the doctors as an instructive case which could be of benefit to many other patients He agreed. At the meeting there were about 60 psychiatrists in the audience, including several prominent psychoanalysts. Irwin was with me on the platform and readily answered questions put to him first by me and then by doctors from the audience. Questioned about his having run away from the state hospital, he said, "I intended to go back after I'd seen Dr. Wertham. I'd bought a round-trip ticket." One psychoanalyst present questioned him closely about his sexual life and he replied very frankly

In a case of this type there is at the one pole of diagnostic possibilities dementia praecox (schizophrenia), which has a serious prognosis and is never fully explainable by psychological data alone. At the opposite pole is the diagnostic label of psychopathic personality, which indicates a mild constitutional mental abnormality not serious enough to be counted a major mental disease (psychosis) Every scientific psychiatrist wishes to find guiding lines in the no-man's land of psychopathic behavior that lies between these poles.

During the discussion of diagnosis at this meeting some doctors favored the diagnosis of schizophrenia and spoke against any further attempts at psychotherapy. I outlined my idea that Irwin's case was outside the group of schizophrenia, that it was a psychologically explainable condition based on a sequence of unconscious emotional factors. Its



ROBERT IRWIN was a sculptor, although his art never mitigated his poverty. As a boy he modeled figures in butter and soap. In this illustration he is making a bust in a reformatory he entered in order to learn a trade.

essential feature was the pattern of violence which appeared to the patient at critical stages of the disease as "the only way out" (catathymic crisis) I expressed my conclusion that he was in a greatly improved stage of the disease but that the pattern of violence was still latent—violence either against himself or against others I added that these cases could recover if they were given prolonged sympathetic and active psychoanalytic psychotherapy, and said I was convinced that if they did get it they could be returned to the stage of recovery and normality.

This discussion was unfortunately of more theoretical value than practical use for Irwin. After the meeting I took him to the admitting office of the hospital and he was returned in the routine way back to the state hospital from which he had eloped.

In May, 1934, Irwin was discharged from the state hospital, and two weeks later he appeared again at my home. He was his same old self. He spoke emphatically and positively. In the state hospital he had been allowed and encouraged to do drawing and sculpture, and that had evidently had a good effect on him. But the fundamental catathymic trend with the "visualization" and the search for a "way out" were still there. He had not written to his mother, but he had turned from his previous bitterness against religion to going to church.

In August, 1934, he told me about a pretty Hungarian girl, Ethel, his landlady's daughter. She helped him with his visualization. He said he made more progress with visualization with her help than he had ever made before. He also talked to her about art and took her to museums.

In the middle of October he obtained a job in the Polyclinic Hospital as an elevator operator and attendant in the doctors' coatroom. When I saw him in December his underlying tension and anxiety were nearer the surface than usual. The Hungarian girl had wearied of him and his visualization. The elevator job was monotonous and poorly paid, and the electric lights bothered his eyes. After he left that job and was unable to find another one his economic condition got so bad that he had to apply for home relief. I advised him as forcibly as I could to return to the state hospital. He agreed.

He stayed there this time for almost two years, with a week's interruption on parole in July, 1936, during which he looked unsuccessfully for employment. In September, 1936, an attendant at the state hospital told him that he might get into the theological school of St. Lawrence University in Canton, N. Y., despite the fact that he had had no high-school education.

His work at the university seems to have been satisfactory. He taught two sculpture classes, one for adults and one for children. The children paid 25 cents a lesson. He had his heart in that work, and was very successful as a teacher.

This time trouble came in the form of a student who broke some of the sculpture made by the children. Irwin was angry and got into a violent fight with him, as a result of which he was dismissed from the university. He went to New York, where he arrived two days before Easter Soon afterward he was sought all over the nation as a fugitive from justice for the murder on Easter Sunday of Mrs. Gedeon, the landlady of a boardinghouse where he had once lived, her daughter, Veronica Gedeon, and a boarder, Frank Byrnes.

EARLIER in that year I had been invited to read a psychiatric paper at

IRWIN DREAMED that an angel patted his head and said: "What do you want?" He said: "I want you."

Johns Hopkins Hospital on the occasion of the 25th anniversary of the Phipps Psychiatric Clinic there. The paper I had prepared was "Catathymic Crisis· A Clinical Entity." Irwin, as a case of violence turned against oneself in the form of attempted self-emasculation, was one of my examples of unrecovered cases in which a recurrence of the pattern of violence (either against himself or against others) could be predicted.

By the time I read the paper in Baltimore the prognosis in Irwin's case had just been fulfilled and I was able to explain in his case the interchangeabilty in catathymic crisis of violence directed against oneself and violence directed against others. Irwin's name as a triple murderer was on every front page as I spoke.

Irwin had arrived in New York from Canton on the 25th of March, 1937. All through the 26th he looked for work, unsuccessfully. On Saturday, March 27, he had a date for lunch with the fiancée of a fellow student at the university She was a pretty and socially prominent young girl of 22.

They had lunch at Schrafft's, then went to the Museum of Natural History to meet her brother, a big-game hunter who had brought back trophies from foreign countries. They tried to get Irwin a job at the museum as a taxidermist, but it fell through. "I was disappointed, but I did not let on, as they tried very hard to get the job for me. So I took the girl alone to the Metropolitan Museum of Art." In the museum Irwin animatedly explained to her the sculpture exhibits, including his favorite *Colleoni* He told her about "the Hungarian girl" and how much she had meant to him in the past. He finally left her on Fifth Avenue. Then he walked the streets. Here he was again, his career at the university abruptly ended, and the last prospect of a job blasted. And the lunch had depleted his cash reserves.

He walked back to the old house where he had lived with the Gedeons and where he had had such high hopes with Ethel and visualization. "That was the bluest and blackest moment of my life " He decided to end it all and went to the East River pier at 53rd Street. He hung around the pier, waiting for it to get dark. He brooded and brooded, looking down at the water. "And then I made up my mind to kill Ethel and go to the chair for it."

Irwin had last seen Ethel in July, 1936, when during his week's parole from the state hospital he visited her and her husband. In December of that same year he had visited Ethel's mother, Mrs Gedeon, and her sister Ronnie at their house and had "pumped" Ronnie to find out how Ethel was getting along He had the wrong impression that Ethel's marriage was broken up and that she was again living with her mother. That is why he went there now in search of her. But first he went to a hardware store, bought a file, and sharpened an ice pick which he had among his things. Then, his mind made up, he walked to the Gedeon home.

When he reached the house at nine o'clock no one was there. He waited until Mrs. Gedeon arrived at 10 and went up with her. A little later he took her Pekingese dog out for his evening walk.

Back at the apartment, he talked with Mrs Gedeon. She had always been very friendly to him and had taken an interest in his well-being. He tried to prolong the conversation as long as possible, for he was convinced that Ethel was living there and would come home eventually. He was determined to stay until she appeared.

After a while Frank Byrnes, a roomer in the apartment and a waiter at the Racquet Club, returned home. Mrs. Gedeon introduced him to Bob and then the boarder went to his room to go to

bed. Continuing to talk with Mrs. Gedeon, Irwin finally got up courage to inquire about Ethel. He was told there was no news about her, that she was not living there. He did not believe it and asked some more questions.

Finally Mrs. Gedeon told him it was getting late and suggested that she wanted to go to sleep now. But Irwin had no intention of leaving. Mrs Gedeon firmly told him he must go, and "at that moment I hit her a terrific blow with my fist and knocked her down. She had plenty of life in her. I grabbed her by the neck. I was astonished at the fight she made. I continued choking her, and in the struggle she kicked me and scratched me something terrible. I had her on the floor. I continued to choke her for about 20 minutes before I was sure she was lifeless. Then her arms dropped back limp and her shoulders sagged to the floor. I still had my overcoat on."

He lifted her body and took it to the adjoining bedroom, where he pushed it under the bed. He washed his face and hands in the bathroom and turned off all the lights. Then he sat down and waited and waited and waited.

Hours later (the evidence points to about three o'clock) the apartment door opened and he heard Ronnie's voice saying good night to someone. She went directly to the bathroom and stayed there for almost an hour. All this time Bob stood hidden in Mrs. Gedeon's darkened bedroom, next to the bathroom door.

Finally Ronnie came out. Before she had a chance to cry out he grabbed her by the throat, carried her to her bedroom, and put her on the bed He kept her there for about two hours. "First of all she said, 'Who are you?' And I don't know whether I answered her or not. The whole night passed to me like a blue daze I said, 'Where is your sister Ethel?' She said, 'She is with her husband.' I said, 'When is she coming home?' And she said, 'She won't come here.' I didn't know what to think."

There were no sexual thoughts in Irwin's mind at that time. His relationship with Ronnie had always been comradely. They had considered themselves as colleagues in art, she a beautiful model and he an up-and-coming sculptor.

While he was talking to her when she was on the bed he had made every effort to disguise his voice. He did not know whether she had recognized him or not. "Finally, at the end, she said to me, 'Bob, I know you are going to get in trouble for this.' The minute she said that I clamped down on her and choked her till she was lifeless."

He returned to the other room and waited in the dark. Then he remembered Byrnes, the boarder. Hours before he had wondered why Byrnes hadn't come in during the rumpus with Mrs. Gedeon. Irwin did not know that Byrnes was a little deaf. When Irwin had entered the apartment he had laid the ice pick on a side table. Now he got it and went into the boarder's room. "Byrnes was asleep. I struck him the first time in the temple, as far as I could go The pick was about six inches long. After sticking him once, the poor fellow lay there twitching but did not bleed. He did not make any outcry I wanted to put him out of his misery, so I stabbed him a number of other blows about his head."

Still no Ethel He frantically went through every drawer in the house for pictures of her. He could not find any. He took two photos of Ronnie. Then he took the small alarm clock and put it in his pocket. About that he said later,

IRWIN SLEPT in the park after his discharge from a convalescent home. Author met him shortly after this.

"Do you know, that's the one thing I'm ashamed of. Stealing that clock. To kill is one thing; but to be a sneak thief—"

As he left the apartment he said to himself, "Buddy, now you've done it."

FROM then on he felt more like a nomad than a fugitive. He stayed in New York for a week, then went on to Philadelphia, then to Washington. In Washington he visited the art museum. Then he went to Cleveland, where he obtained a job as a bar attendant in a hotel. After being in Cleveland a short while he had an experience which moved him so profoundly that he almost gave himself up at once. He read in the public library that his mother had died. That made everything different. Now he could never go home to his mother after having made something of himself. So he might as well give himself up and die now. But he did not—not yet.

On June 25, when a young girl who also worked in the hotel recognized his picture in a detective magazine, he quietly left town for Chicago. There he gave himself up to the Hearst papers on a contract that he would tell them on the spot the story of his life and of the murders if they would in return pay him $5,000, most of which was to go to his two brothers.

The newspapers, beginning with the opening blaze of the Hearst papers' scoop, were having a field day. Almost every story was accompanied by retouched nude or seminude photographs of the beautiful murdered model. The stories went into every detail, real and fanciful. Irwin commented later that many of their details were untrue, "besides being abominably written." The columnists cracked their quips. In the "Sun Dial" of the New York *Sun* there was a verse:

IT'S ALL DONE BY MIRRORS!
He did not murder anyone
And such a charge not nice is:
He's just the charming victim of
A "catathymic crisis."

Slowly the wheels of the law began to move. *Parturiunt montes, nascetur ridiculus mus.* The mountains labor, and bring forth a little mouse. Justice in all its majesty labored and produced a lunacy commission.

I was called before the commission seven times and testified for many hours. The proceedings were strange. On the one hand, it was like a friendly get-together, with a lot of smoking and small talk. On the other hand, it affected all kinds of rules, procedures, and formalities such as belong to a real trial: arguments between the District Attorney and the lawyer, objections and rulings by the chairman or by the commission as a whole. If human lives had not been at stake it would have been an amusing caricature. But lives were at stake: not only the life of Robert Irwin, for whom the electric chair had more allure than terror, but also the lives of the many Irwins, Gedeons, and Byrneses of the future.

I stated under oath:

1. That Irwin suffered from a mental disease every time I saw him.
2. That he always suffered from the same mental disease.
3. That if he had not had this mental disease and if his—to my knowledge—decent personality had not been affected by this mental disease, these three murders would not have been committed by him.
4. That these three murders were in my opinion definite symptoms of his mental disease.
5. That he was not in full possession of his mental powers during the night of the murder.

That lunacy commission sat for seven months! The testimony taken at the proceedings (and not all testimony was kept on the record) amounted to 756 type-

written pages, of which 311 pages were testimony given by me One sentence in the final report has already become a classic: "The fact that in reaching its conclusion the commission has not been able to interrogate Irwin [Irwin had refused to speak to them] should be noted in passing." "In passing"!

The man in charge of the Irwin prosecution was the chief of the Homicide Bureau, Mr. Jack Rosenblum. Mr. Rosenblum was a little shocked that I defended the right of Robert Irwin as a sick man not to be electrocuted. Once he asked me, "What *is* your social philosophy?" I told *him* testifying in murder cases was not my profession and that was why I could do scientific research on the subject. Practically, my interest was prevention. "There is one man in this case," I said, "who tried his hardest all along to prevent these murders. And that man is Robert Irwin. If you add it all up," I went on, "he presented himself *10 times* within four and a half years to the proper medical agencies to ask for help. Did he get it?"

In November, 1938, he faced a partially filled jury box. The first day was spent with the selection of jurors. The next day, after a consultation of counsel, a plea of second-degree murder was suggested and accepted Mr. Leibowitz told me that this came about entirely through my stand. Later I learned that of the dozens of psychiatrists who had had contact with Irwin, who had kept him for years in state hospitals, diagnosed him as a case of schizophrenia with bad prognosis and what not, I was the only one who kept insisting that he was legally insane.

Now the legal part was over with. The plea excluded the electric chair. The sentence to be pronounced later would be only a matter of arithmetic. It was merely a question of how many legal years a life sentence can have.

When the curtain rose on the finale in the courtroom Irwin was all prepared for his speech to clear his "wounded name."

"Robert Irwin," intoned the clerk, "have you anything to say before sentence is pronounced upon you?"

There was a tense silence. Irwin cleared his throat. He began to speak in careful, measured tones.

The judge interrupted him to say that he had already pleaded guilty and that the court wished to hear no extended oration. Irwin tried to break in, but the judge went on to recite the facts of the indictments and plea, and announced the results of his additions: "One hundred and thirty-nine years."

The end of the story is best summed up in the words of the published report for 1939 of a psychiatric "Committee on the Legal Aspects of Psychiatry": "An interesting sequel of the Irwin case is that the District Attorney, apparently convinced that the lunacy commission's report would not be sustained as a result of a trial, accepted a plea of guilty in the second degree, and that within about 10 days of the prisoner's reception at Sing Sing he was found by the prison physicians to be psychotic and was transferred to the state hospital for the criminal insane."

ROBERT IRWIN was a gifted and promising young artist. His was fundamentally a decent, unselfish, loyal character. What had gone wrong with him?

Speaking of the night before Easter Sunday, 1937, Irwin said, "Every bit of it was accidental." That was a sincere statement. He intended to annihilate Ethel—and instead killed three other people. But when he used the term "accidental," that meant only that the causes, the design, were hidden from him. If one understands the conscious and unconscious workings of his mind, there are layers of patterns woven into one another.

DREAM LEOPARD reminded Irwin of "Schopenhauer's will that devoured everything it [encountered]."

The most superficial of the hidden patterns behind his action is called the Herostratus complex. Herostratus was the ancient Greek who deliberately set fire to one of the most renowned buildings of his time, the temple of Diana at Ephesus. He gave as his reason that he wanted to do something by which he would be famous through all the ages. He accomplished this goal. His name has become a byword and is known to many who do not know the names of the heroes of Thermopylae, the Bastille or Stalingrad. Herostratus must have suffered from some tremendous frustration, some overwhelming inferiority, that made him seek acclaim and punishment at the same time.

Irwin also wanted acclaim. It was much more than the artist's desire for communication with a public. He wanted omniscience—and that, of course, means knowing more than all the others. He was willing to pay for that the highest price. Like the Nordic supergod Wotan who sacrificed one eye to get omniscience, he was willing to sacrifice his sex organ. After the murders he first thought of giving himself up to Walter Winchell, then gave himself up to a big newspaper chain and evidently enjoyed the proceedings. The price was life, either the electric chair or life imprisonment. He did not have to give himself up, for his chances of escape for a long time were excellent.

What interested him most about his trial was the show, the contest, and—after he had taken the plea—the little speech he was going to make. Many people daydream such events, but he acted them. Even the murder night had an element of bravado in its scope and ferocity.

Another of the more superficial patterns is what I like to call the flight into custody. In regions and periods where the inmates of state hospitals and correctional institutions are humanely treated, one can find individuals who again and again voluntarily give up their freedom to surrender themselves to the custody of the authorities I knew an alcoholic patient once who had done so 176 times. In the old German psychiatry such people were called *Anstaltsbummler.* Of course bad social conditions on the outside have something to do with it. But there is such a thing as an emotional drive to flee from accustomed surroundings and place oneself in the hands of official custodians. Irwin did that when at the age of 18 he had himself committed to the State Training School, and again later when he went to the psychiatric hospital, and still later when he willingly returned again and again to the custody of the state hospital.

Years before the murder, when Irwin was still for me merely a case of attempted self-emasculation—and not yet a case of murder—psychoanalytic study had revealed that his emotional conflict centered on his mother. However he rationalized his ideas of visualization, it was to his mother that he wanted to return in the glory of his attainment The conflict between infantilistic conquest of his mother and elimination of her image by flight or violence was the secret, unconscious blueprint that guided his life. His whole life was a flight from her.

The victims of the murder night were not so "accidental" as they seemed to him. On the murder night the original family constellation was repeated. Mrs. Gedeon was one of those psychological mother-substitutes that recurred throughout the course of his life. Her first name, by which he called her, was the same as his mother's. Her murder, precipitated by her refusal to let him see Ethel, was in its deeper motivations a symbolic matricide.

Mr. Gedeon was absent—in fact, he was living away from the family, somewhat as Irwin's father had done. The father-image for Irwin had been a friendly one. He had met the Gedeons first about two weeks before he came to the hospital in 1932. When he went back to see them in 1934 he went first to see

Mr. Gedeon, whom he liked. On that occasion he met again the women of the household and decided to move into the house as a boarder.

Frank Byrnes was no more killed because Irwin thought he was eavesdropping than was Polonius, who did listen from behind the arras. Irwin, like Hamlet, was frustrated in killing the one whom he wanted to kill (Polonius in *Hamlet* was a father figure, Byrnes was a brother figure.)

In their development in time, the stages of Irwin's life leading up to the tragedy of the murders follow the five stages of the catathymic crisis.

I. The stage of initial thinking disorders, which follows the original precipitating circumstances.

II. The stage of the crystallization of a plan, when the idea of a violent act emerges into consciousness

III. The stage of extreme tension, culminating in the violent crisis, in which a violent act against oneself or others is attempted or carried out.

IV. The stage of superficial normality, beginning with a period of lifting of tension and calmness immediately after the violent act.

V. The stage of insight and recovery, with the re-establishment of an inner equilibrium.

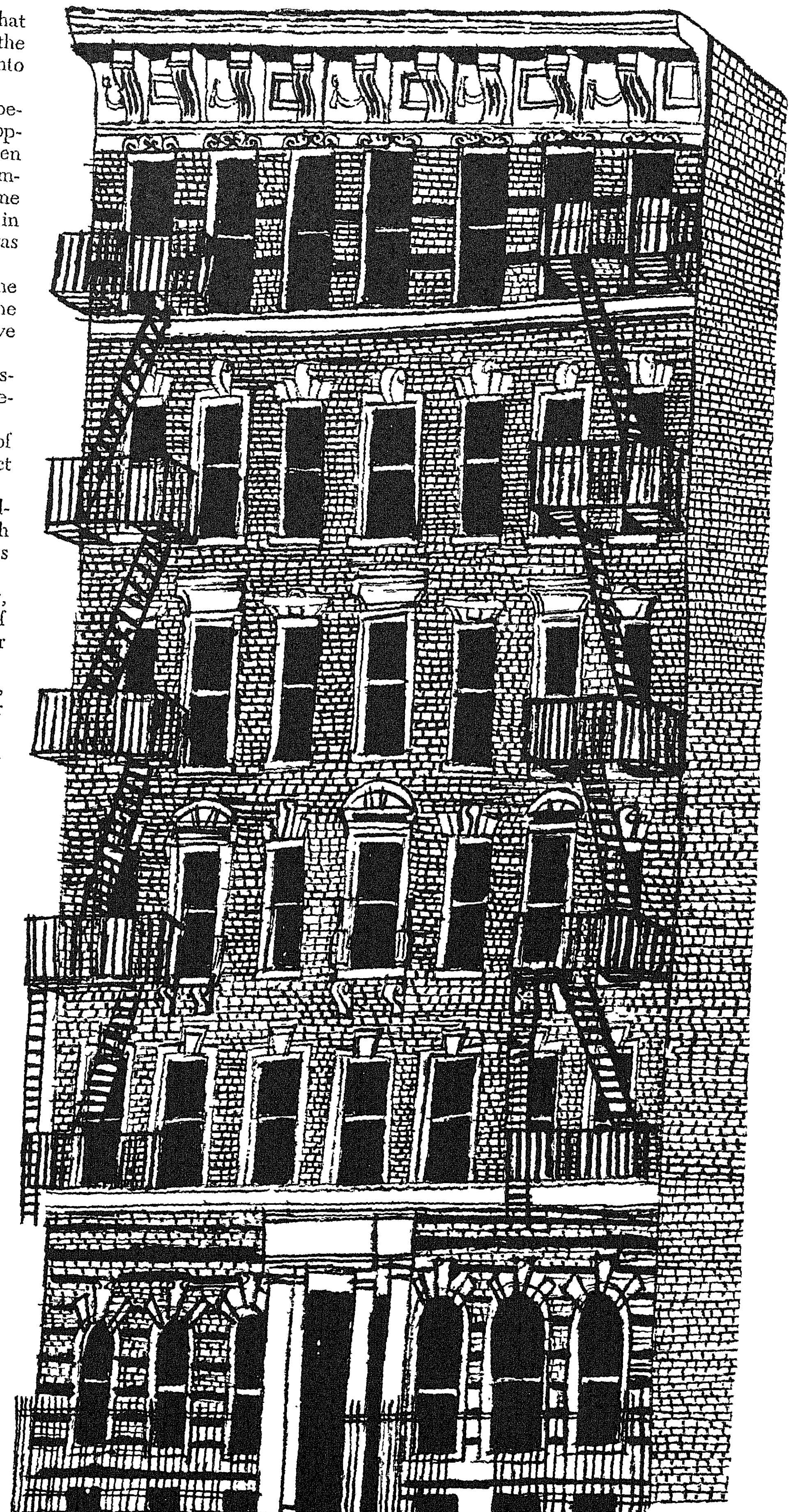
A case like Irwin's cannot be summed up in a Greek word. But at its minimum the designation catathymic crisis indicates that there is a pathological condition with a beginning and a course, and excludes the unpsychological claim that Irwin was a case of schizophrenia (dementia praecox), ununderstandable, bizarre, and "incurable."

The intervening years, like an experiment, have confirmed my diagnostic opinion. I have had letters from him off and on. They are warm and close, showing no trace of schizophrenic withdrawal. Several of his doctors have informed me personally that "he shows no mental deterioration."

Last winter I received a letter from Irwin. He told me how he was getting along, inquired about my health, and spoke about the cold weather. Then he wrote that he had found a sparrow with one foot frozen off. "I am keeping it in a box," he wrote, "but I'm afraid it will die. I don't want to kill it. And yet it cannot possibly live if I turn it free. So what shall I do? Anyway, this is a tough world for a lot of people, including sparrows."

Ever since I got that letter I have been unable to dismiss the question from my mind: Did society ever show as much concern for sick Robert Irwin as he showed for a sick sparrow?

Fredric Wertham is a psychiatrist and is author of the book Dark Legend.



THE HOUSE where Irwin murdered Mrs. Mary Gedeon, her daughter Veronica and a boarder named Frank Byrnes is on Manhattan's East Side. Irwin went there on March 27, 1937, and waited until his victims came home.

THEODOR ROSEBURY is now associate professor of bacteriology at New York's College of Physicians and Surgeons. During the war he was head of the airborne infection project at Camp Detrick, of which his book tells little.

by James R. Newman

PEACE OR PESTILENCE, by Theodor Rosebury. Whittlesey House ($2.75).

ON the whole I found this a less horrifying book than I had expected. Perhaps this is because the uncertainties of biological warfare, of which there are many, are seized upon as proof that the entire business is only a nightmare; perhaps it is that, having got used to Hiroshima, the mind cannot be expected to boggle at the thought of employing germs to "extend policy by other means." As a matter of fact, Dr. Rosebury argues that from the standpoint of the receiving population biological warfare, or BW, is probably no worse than atomic bombs. Physicists, we are told, most dread the biologists' handiwork, while biologists, presumably on more familiar terms with germs, regard the atomic bomb as the peak of human savagery. At any rate, it is with commendable restraint that *Peace or Pestilence* unfolds its account of unlimited evil begotten by tribal fear.

The idea of using germs to exterminate the enemy is not, as might be supposed, of recent origin. It is said that in the 16th century Francisco Pizarro distributed clothing contaminated by smallpox among the *Peruvian Indians* (allegedly there were three million victims); there is better evidence for believing that in 1763 General Amherst, Governor of Nova Scotia, pursued the same practice among the native tribes of Canada. Pasteur used a fowl-cholera bacillus to destroy an army of rabbits that made the foolish mistake of disturbing the champagne bottles of Madame Pommery's famous cellars in Rheims. In more recent times the notion of utilizing disease organisms for military purposes first occurred to the Germans. The Merck Report (the 1946 *Report to the Secretary of War on Biological Warfare*) notes that "there is incontrovertible evidence . . . that in 1915 German agents inoculated horses and cattle leaving U. S. ports for shipment to the Allies with disease-producing bacteria"; similar attempts were made or planned by the Germans elsewhere. Since the early 1930s most of the major powers have had some sort of BW research under way. Inconclusive but suggestive scraps of information about both Russian and

BOOKS

A bacteriologist's account of biological warfare, the underpublicized complement of the atomic bomb

German activities have emanated from various sources; Japan, the Merck Report discloses, was working on BW "intensively" from 1936 until 1945; our own major project at Camp Detrick, Md., was established under the U. S. Army Chemical Corps in 1943.

Almost nothing is known about the progress of Army research in this field. Shortly after the war the security lid was lifted a little but quickly clamped on again; BW facts are now more closely guarded than the facts about atomic bombs. It is known that Camp Detrick is "one of the biggest and best-equipped installations in the world for biological research and development"; that during the war it employed almost 4,000 persons, and that its present staff, while somewhat smaller, is no less skilled; that there are special "field-testing" facilities for BW in Mississippi and Utah; that in 1948 a single appropriation item for Camp Detrick came to $850,000. There have also been published a few reports and technical papers apparently no longer considered of military value. This comes close to being the sum of public knowledge. Dr. Rosebury's book is therefore welcome even though, because of existing restrictions, he has not been able to draw on his wartime experience as a bacteriologist at Camp Detrick.

BW, as Rosebury points out, is "bacteriology upside down." The normal parent science is concerned with understanding the behavior of germs for the purpose of arresting disease; its inverted offspring is concerned with understanding the behavior of germs for the purpose of spreading disease. How to infect large numbers of persons, how to find and utilize the best carriers of disease, how to "alter the hereditary constitution of bacteria" so as to produce new strains which will be highly infectious yet resistant to high pressure, temperature and so on, how to poison animals and vegetation, how to promote epidemics: these are the exercises of the upside down discipline which appears right side up to a world standing on its head.

At first glance the choice of infectious microorganisms for aggressive ends seems rich beyond the dream of military planners. Among the potentially useful bacterial diseases are tularemia, plague and melioidosis; cerebrospinal meningitis, cholera, typhoid and the bacillary dysenteries. The spirochetes offer relapsing fever and infective jaundice; the protozoa, malaria; the rickettsiae, typhus fever, scrub typhus and Rocky Mountain spotted fever; the viruses, psittacosis, yellow fever, dengue, influenza, measles, mumps and infantile paralysis. Rinderpest, foot-and-mouth disease, hog cholera and fowl plague merit attention because of their effect on animals.

From this aggregate the military, it might be thought, need only select the cultures easiest to produce and store to have an incomparable set of weapons at their disposal. Several factors, however, narrow the choice of diseases and limit the range of BW. This at least is the situation at present. For example, BW is "distinctive among forms of warfare in its requirement that the weapon be not merely aimed at the target but also suited for it." There are, as previously indicated, agents effective against man yet impotent against animals; man, in turn, is invulnerable to many diseases affecting both plants and animals. The bacterium best suited for containing communism has not been determined.

Killing the enemy, Rosebury observes, is neither the only nor always the best of military objectives. This principle does not stem from the latent humanitarianism of generals; military thinkers merely consider "incapacitation preferable to killing, since the sick tie up medical personnel and hospital facilities and otherwise drain the resources and impede the movements of the force that must care for them." Diseases that would spread "somewhat but not too much" are highly favored for special operations: for instance, where the target city is to be captured, the disease arrested and the survivors put back to work. If the inhabitants of Topeka were all killed in a single raid it would be less of a disaster from our own military standpoint than if a third of the population contracted psittacosis; similarly, our chiefs of staff might regard the planting of a full-scale epidemic of smallpox in Minsk as a more valuable military achievement than wiping out the city overnight.

What are the principal criteria for the selection and application of BW agents? Rosebury's list includes "infectivity," "availability," "epidemicity," "therapy," "detection," "casualty effectiveness," "resistance," "retroactivity," "means of transmission." Most of these items are self-explanatory though a few require brief comment.

With respect to "infectivity" and "casualty effectiveness" you may recall the sensational articles of a couple of years ago announcing the extraordinary lethal properties of botulinus, a toxin produced by *Clostridium botulinum*. A single ounce of the pure toxin, it was claimed, could kill 200 million or more persons. The basis for this assertion was a series of experiments in which minute quantities of the toxin were injected into the most uncomplaining of laboratory assistants, white mice.

Simple arithmetic then gave the conclusions applicable to human beings. It is surprising that the newspapers overlooked other and more unpleasant possibilities. Milligram for milligram the pneumococcus is 20 times as effective as botulinus; the streptococcus (in its capacity for producing sore throats), 100 times; the tularemia bacillus, 15,000 times. But it is essential to realize that this is a theoretical maximum for infection without regard to resistance, therapy, epidemicity and other factors. Entirely apart from these factors the botulinus story was both mischievous and stupid. Botulinus is a toxin, not a self-propagating disease; it would have to be spread by hand; it would probably be as feasible to kill millions of persons with a hatpin as with botulinus. Theoretically, however, it is possible.

Resistance refers to the infective agents' "capacity to withstand environmental influences that are in some degree destructive, like drying, the ultraviolet radiation in sunlight, high temperatures, or high concentrations of disinfectants." It is also necessary that the germ maintain its virulence under field conditions. Some organisms are unusually hardy: the spirochetes of relapsing fever remained alive and virulent in ticks that had been starved for five years; others, like the tularemia bacillus or the spirochete of syphilis, are extremely delicate, dying quickly unless hospitably treated. Even fragile agents, however, may be useful, since any germ crossed with hardier strains can probably be "stabilized" while retaining its infectivity.

Retroactivity—an awkward word for conveying Rosebury's thought—refers to the possibility of backfire when using BW agents. What is the chance that a given disease bacillus, used offensively, would infect the civilian population or the troops of the nation using it? A broad answer to the question is manifestly impossible. The danger of boomerang epidemics would depend on the agent used, on the terrain, the climate and the other conditions of the conflict. Laboratory research on BW agents is perilous, but this problem was "satisfactorily solved" during the last war even for the deadliest

toxins and organisms. Large-scale production under safe conditions of cultures such as the virulent psittacosis "soup" is another matter; and as for the risks to the attacker of actual germ warfare, Rosebury offers only speculative and not necessarily reassuring conjectures.

When suitable, hardy, virulent, self-propagating agents—preferably germs that will eat the enemy but have no taste for the attacker—have finally been selected, when satisfactory methods of producing and storing BW cultures in quantity have been found, there still remains the most intricate and uncertain aspect of BW—the manner of transmitting the bacilli. No one really knows, Rosebury admits, what germ bombs can do and "how one [can] get them to do it." The small field tests carried out thus far, however useful, provide no assurance that disease germs can effectively be spread in wartime. Water and food supply undoubtedly can be contaminated by saboteurs, but it seems doubtful that this method would lend itself to widespread and repeated operations. Brucellosis, a disease which under natural conditions spreads "uncontrollably" among animals, could, Rosebury thinks, be used cheaply and easily once there were access to enemy territory. The spreading of bacilli by hand, however intrepid and ingenious the saboteurs, is clearly inferior to spreading by air, provided this method is at all feasible. The aim would be to disperse "clouds of bacilli" over densely populated areas.

Despite the uncertainties and difficulties involved, Rosebury entertains "no serious doubts" that successful BW is "not beyond the ken of human genius." The necessary cultures can, he believes, be produced in great quantity; the dissemination mechanism, while perhaps entailing novelties of design, cannot continue to elude our ingenuity; the synthesis of epidemics, though a new science, will not defeat scientists if they are assured of "adequate funds, space and assistance."

I do not altogether share Rosebury's faith in the ability of science and technology to solve each of the problems he has set forth. His discussion of defenses against BW seems thoroughly inadequate, however valid his conclusions may be: "As a whole [the defense] is pitiably weak." A more serious deficiency is his failure to consider how the machinery for disseminating BW could be brought to the target. P. M. S. Blackett's *Fear, War, and the Bomb* has made at least three points clear: first, that in a war between Russia and the U. S. each would face special difficulties in conveying bombs to the respective target areas; second, that guided missiles cannot yet be depended on to reach the mark; third, that fighter and other defenses appear, for the time being, to hold a real advantage over the larger and heavier bombers. I fail to see why these points do not apply to BW bombs or other dispersing machinery Their validity, to be sure, is only temporary, but in discussing the character of future warfare, especially under the present superheated conditions, it would be better to limit speculation to probabilities and to foreseeable events. Too frequently Rosebury's predictions depend on a chain of doubtful "ifs" and precarious hypotheticals

The last third of *Peace or Pestilence* is devoted to a sincere plea for sanity and moderation in Soviet-American affairs. The gist of the argument is that men can have peace if they want it and that the alternative, another war, even if BW plays no part, is certain to effect the irretrievable ruin of a large portion of the globe. The future of all life may be hideously twisted by the aftereffects of either atomic bombs or biological warfare. To believe that a war entailing such consequences could at the same time preserve democracy and uphold the "dignity of the individual" is surely insane as well as monstrous. Perhaps it is no more deranged than the notion that preparation for war can safeguard peace. It would be well to recall the "bitter lesson of history" as stated by Viscount Grey of Fallodon in his memoirs:

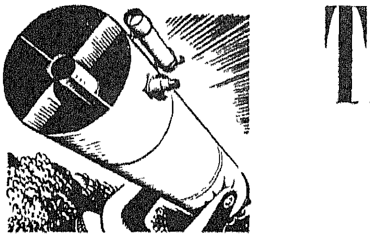
"Great armaments lead inevitably to war. . . . The increase of armaments that is intended in each nation to produce consciousness of strength and a sense of security, does not produce these effects. On the contrary, it produces a consciousness of the strength of other nations and a sense of fear. Fear begets suspicion and distrust and evil imagining of all sorts . . . it was these that made war [in 1914] inevitable."

MUST WE HIDE?, by R. E. Lapp. Addison-Wesley Press ($3.00). "No," says Dr. Lapp, presumably answering Dr. (*No Place to Hide*) Bradley. Lapp, a physicist who worked on the Manhattan Project, does not foresee atomic warfare in the near future. He judges Russia unable to mount a heavy assault before 1960 or even later; he believes feasible defense measures, including some moves toward decentralization, would substantially mitigate the effect of atomic bomb attacks if and when launched against us; he dismisses as militarily unimportant the damage saboteurs might inflict with a few "smuggled" bombs; he is equally skeptical about long-range guided missiles and the vaunted powers of the B-36. Lapp believes that if war cannot be prevented we might succeed in a "limited" offensive, *i.e.*, by an "initial air blitz" which would cause the Russians to change their minds. Meanwhile we should continue our present policies. His political insight (and his style) are typified in the following passage: "Since war is to be brought home to the Russian people, it is clear that psychological and

social forces may be more important than purely military weapons. One recalls, for instance, how amazed Russian soldiers were to discover that privates in the American Army wore wrist watches. Communist teachings were given a severe jolt by these minor incidents. Many such subtle approaches can be followed and more would evolve from serious thinking on the subject."

CHILDREN DISCOVER ARITHMETIC: AN INTRODUCTION TO STRUCTURAL ARITHMETIC, by Catherine Stern. Harper and Brothers ($4.50). A recent story in *The New Yorker* told of a man who did arithmetic by running the tip of his tongue over the points of imaginary dominoes on the roof of his mouth. Most adults would be satisfied if they could do as well, and there is no lack of additional evidence to show that the teaching of elementary arithmetic is in need of repair. In this book a highly gifted, imaginative educator with a sound training in both mathematics and psychology presents a fresh approach to the pedagogy of arithmetic, based upon years of actual experience. With the aid of simple, inexpensive equipment and as part of their play activity, Dr. Stern, Director of the Castle School in New York City, teaches ordinary children, some as young as two and a half, "the first steps in quantitative thinking." Eliminating the usual counting procedure, she substitutes in its place the matching of congruent blocks, the fitting of different blocks into slots of corresponding length, and so on. Only after the child knows every combination of the blocks which adds up to 10 are the number names introduced. This Gestalt or structural method is then extended to all the operations of arithmetic, to fractions, decimals and to numbers of every size.

A HISTORY OF SCIENCE, by Sir William Dampier. The Macmillan Company ($3.95). A fourth revised and enlarged edition of this standard work carrying the account of scientific events through the war years. For all its merits, which are considerable—indeed, in scope and readability there is no comparable account—Dampier's scholarly work is inadequate in its treatment of psychology, sociology and the other social sciences; a worse defect is its failure to consider the social function of science, the economic and related aspects of modern organized research and the impact of the problems of contemporary society on the scientist and his work. Nonetheless, Dampier's more conventional approach to his vast subject, along lines similar to those followed by William Whewell a century ago in his famous *History of the Inductive Sciences,* has the advantage of being straightforward and unencumbered by contentious issues, and the book unquestionably deserves its high reputation.
J. R. N.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

SETTING circles are graduated rings that enable the astronomer to set his telescope exactly on desired celestial objects, from coordinates given in published lists, without even looking at the sky. Since these circles are a luxury, they are not usually fitted to the beginner's telescope. This is good, because it compels him to learn the skies. The larger instruments that amateurs usually build after a year or two are generally equipped with setting circles, one attached to the polar axis to indicate celestial longitude, the other on the declination axis to show celestial latitude.

Ralph Ingels Fenn of Kokomo, Ind., has placed his circles on the inside wall of his observatory instead of on his telescope, and he has connected them with his telescope by means of Selsyn electric position-indicating equipment. The illustrations below show the Selsyn transmitters, the concrete pedestal of the telescope, and the circles and indicators on the wall.

All this may seem to be unnecessary complication, but Fenn correctly states that "we have found this much more satisfactory for a small observatory and telescope than the standard circles mounted directly on the respective axes of the telescope. They are out of the way, and the figures may be made much larger, more legible and better illuminated without interfering with the telescope. "I hope," Fenn concludes, "that others will enjoy using Selsyns as much as we do."

Through their use on aircraft and elsewhere as position indicators, Selsyns have become widely known. Each transmitter is connected electrically to its rotor and indicating pointer. The rotor mimics with high accuracy any and all motions of the transmitter, whether fast or imperceptibly slow, forward or backward, regular or irregular, so that the two function as if mechanically geared together. This is true whether the three-wire circuit that connects them is an inch or miles in length. So surprising is this mimicry that the novice usually tries to fool the indicator by turning the transmitter in irregular ways. The party fooled will always be that of the first part, however, for the transmitter and rotor pairs are inexorably "geared" together by electrical forces, and they work as one.

Selsyns, made by the General Electric Company, are induction motors with three-coil, three-phase wound rotors. Their popular designation as motors is correct, but misleading, since they are seldom called on to spin rapidly as most familiar motors do.

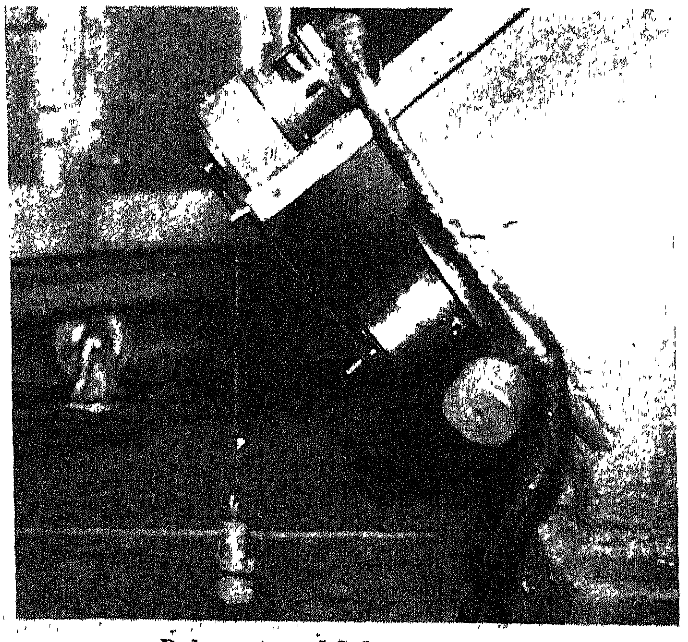
"I attached one indicator to the concrete pier of my telescope," Fenn writes, "so that its shaft would be precisely parallel with the polar axis, and another indicator parallel to the declination axis. Cords running on these axes transmit the angular rotation of the telescope to the Selsyn transmitters through pulleys of exactly equal diameter, arranged so that transmitter and indicator will turn in the same direction. Small weights at the ends of the cords keep the slack taken up. I did not have space to use gear trains instead of cords.

"My Selsyns were surplus-stock railroad-signal equipment designed to work on 45-volt direct current, but were easily converted for 110-volt 60-cycle alternating current by the insertion of an electrolytic condenser, following instructions included with them.

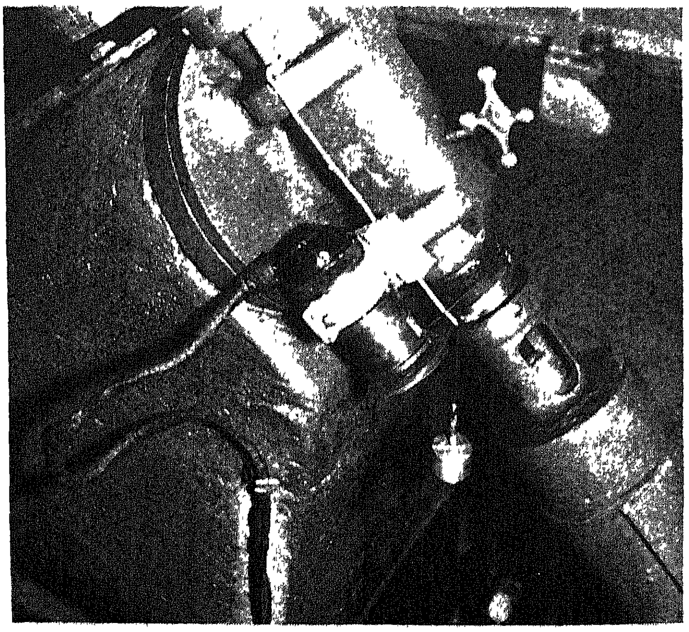
"The impulses from the transmitters are carried by triple wires to the indicators. These are equipped with nine-inch dials of heavy paper, with the numerals for the hour angles and degrees printed on them in India ink and lacquered over. They are recessed in a frame with concealed lights (red, very dim) at either side.

"When I first go out at night I focus my telescope on some bright star that I am familiar with, center it in the field, look up its right ascension and declination in the star atlas, and then, after raising the drive cord off the transmitter pulley, I turn it manually until the dial reading is correct. The same procedure is followed for the declination. From then on I can forget local time. To find an object I need only point the telescope to its coordinates listed in the atlas. Once the basic time for a known star is taken, all other stars maintain their respective locations for that night. This is essentially the principle of the slip ring that is described by Russell W. Porter in *Amateur Telescope Making*, page 145.

"I once heard Mr. Porter say that he hoped all amateurs' telescopes that are on fixed mountings would some day be



Polar axis and Selsyn transmitter



Declination axis and transmitter

equipped with Selsyns, and that one need only operate a telescope thus equipped to appreciate the convenience and accuracy they offer. From experience I confirm this enthusiastically. Mine are a great improvement over the circles on the telescope, as I formerly used them."

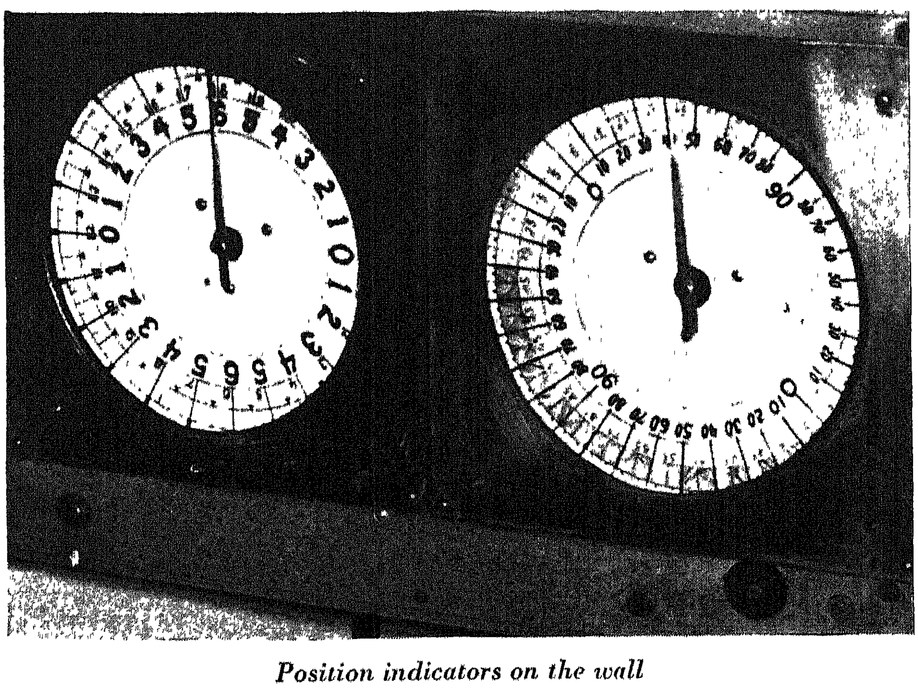
DISCOVERY of a star within only six light-years of the sun has been announced by Dr. Willem J. Luyten, director of the astronomical observatory at the University of Minnesota. It has been named L 726-8, the letter L being in honor of the discoverer, following an established custom in the astronomical world. Only two stars, Proxima and Alpha Centauri, both 4.3 light-years distant, are nearer the solar system than L 726 8. The newly discovered star is a double of the visual type. Both components are extremely dim red objects, visible only in very large telescopes. A short time ago one of them flared up in an atomic explosion.

A few of the textbooks of astronomy contain lists of the very nearest stars to our solar system. Though these have no special significance, they are of some interest as our nearest neighbors in outer space. An uncommonly full list of these prepared by the astronomer G. P. Kuiper appears in William T. Skilling and Robert S. Richardson's *Astronomy*. It names 29 stars within a radius of 12.7 light-years of the sun. Even this short distance relative to known space, only 75 trillion miles, is virtually meaningless, since the human mind cannot conceive a greater distance than a human being can traverse and then look back across. If we try to imagine or conceive a greater distance than this, such as the 3,000 miles we may have traveled from ocean to ocean, we succeed only in a kind of additive or synthetic fashion, by attempting to combine the separate "looks." Only by some kind of abstraction or miniature of the reality, such as a map or globe, can we imagine or think we imagine even 3,000 miles. Large as is the 75-trillion-mile radius of the nearby sphere of space containing 29 (now 30) known stars, it represents approximately one hundred-millionth the radius of known space, the billion light-years which has already been reached by the 200-inch telescope on preliminary trials.

The very nearby stars do not form a system, they are simply the stars that are near us or, more pointedly, that we are near. Within this tiny, spherical bit of the universe there are two stars, Sirius and Procyon, which are respectively 21 and 5.8 times brighter than the sun; Alpha Centauri, which just equals the sun in brightness; and 27 others much dimmer than the sun. Most of these are "cool" bodies of type M, with a temperature of 3,000 degrees C. or lower.

L 726-8 is a binary star with a period of revolution of 20 to 25 years; its exact period cannot be determined for many years to come. The two components, one of which is 10,000 and the other 60,000 times less bright than the sun, are something less than 300 million miles apart. Together they are moving away from the solar system at 26 miles a second. Thirty thousand years ago they were very much nearer than they are at the present time.

Both components of the double star are surrounded by huge clouds of incandescent hydrogen and calcium gas. On December 7, 1948, the fainter component was seen to flare up suddenly to 12 times its normal brightness, and subside within 20 minutes. Here, Dr. Luyten said, is a phenomenon that is thus far unique among the stars. "In this very



Position indicators on the wall

faint star the atomic explosion—for such it must have been—amounted to the equivalent of a billion atomic bombs of the Hiroshima type."

The discovery of L 726-8 was not made visually, but by comparing photographic plates made by Dr. Luyten in 1930 at the Harvard University Observatory in South Africa with plates that were taken by him at the same observatory in 1944, and with other plates that were made at the University of Arizona and at the Union Observatory in Johannesburg, South Africa.

Dr. Luyten was the discoverer of another dim star only 9.9 light-years from the sun This bears the designation L 789-6. He is best known for his discovery of 70 white-dwarf stars of the type having exceedingly high density Born in the Netherlands East Indies, he came to this country in 1921 and was connected with the Harvard College Observatory from 1923 to 1930.

If every amateur telescope maker were given an optical flat perhaps one foot in diameter, it no doubt would quickly become customary to test paraboloidal mirrors for reflecting telescopes at the focus, instead of at the center of curvature. (The latter is now the usual method because few own the necessary flats.) Testing would then be simpler and, some assert, twice as precise. The worker would not seek to obtain the conventional mirror shadows, but instead would alter his mirror so as to eliminate all shadows This test at the focus is explained in *Amateur Telescope Making*, page 16.

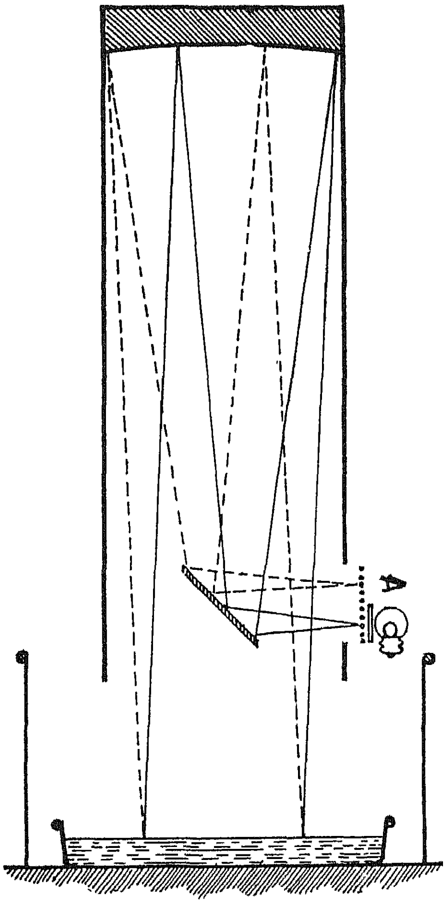
As a secondary result of the universal possession of flats, refractors might become as plentiful as reflectors, which may be made without a flat as an accessory; they might become more plentiful, in fact, since many consider them superior.

While glass flats do not grow on every bush, the principal ingredient of a liquid flat costing only a dollar or two does grow at every filling station. It is a pan of common lubricating oil. The same Robert L. Waland of St. Andrews, Scotland, who made the exquisite six-inch refractor described in this department last July has experimented with oil flats and made them perform satisfactorily. He has used his technique to make 3½- and 6-inch achromatic lenses; in fact, he was able to work their surfaces to one-eighth wavelength tolerance—four times as close as necessary for an objective lens.

Waland's first drawing shows how a mirror may be tested with an oil flat, an arrangement somewhat comparable with the one in *Amateur Telescope Making*, page 15, except that a Ronchi test grating is used instead of a knife-edge. The secondary mirror shown may be aluminized, or a prism used, to gain added and usually needed reflectivity. By using a slit and a 35-watt headlight bulb shielded from the tester's eye, Waland obtains enough reflected light to make the test

This test is not recommended for mirrors larger than about 10 inches, because of the sag in their necessary edge-supported, horizontal position. A poor secondary mirror also will impair the test, just as it will impair the performance of the telescope—often causing the eyepiece or primary mirror to be wrongly blamed

The second Waland drawing shows the oil flat as used in the autocollimation



Oil flat for mirror testing

test of an objective lens. The lens lies in its cell, which rests on a circular wooden frame (shown also in elevation) with three equidistant leveling screws.

Now some precautions Waland gives on the basis of his experience.

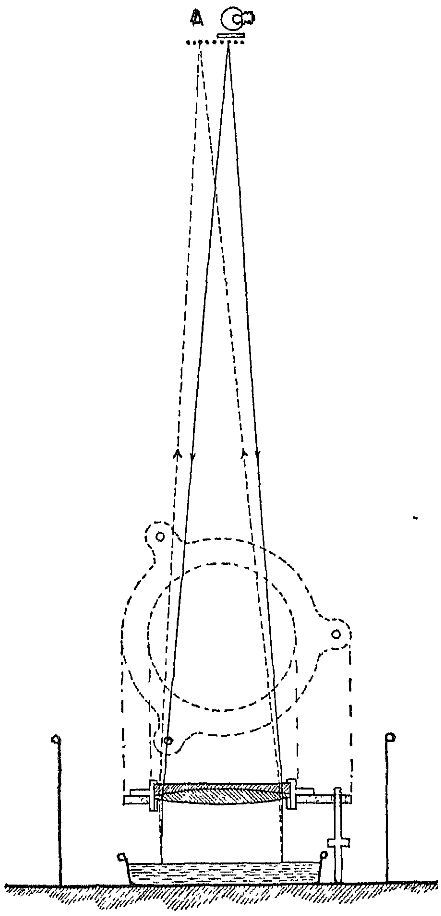
1. The oil, a medium "lube," should be placed in a container at least two inches greater in diameter than the lens or mirror, to avoid capillary effects at the edge

2. The container should rest on a rigid foundation, not on a wooden floor.

3. The oil should be clean and free from surface dust. If dust disturbs the surface a strip of metal should be trailed over it to draw the particles to one side. If a few particles persist, no harm will result, since the worker can easily recognize and ignore them. However,

Waland explains, "I have not used the knife-edge test with oil; I use the Ronchi test. With the grating very near the focal plane, so that about two lines traverse the surface, it is very easy to differentiate between optical errors and local disturbances of the surface due to dust and so on. But I should imagine that the oil surface would have to be particularly clean for the knife-edge test; otherwise it would be confusing."

4. Calm days are best, wind outdoors disturbs the oil surface. Slamming doors, footsteps, heavy traffic in the neighborhood or other human disturbances may limit use of the oil flat to the late hours of the night.



An arrangement for lens testing

5. Even on calm days a draft excluder should be placed round the container, as shown in the drawings. This should reach three or four inches above the oil, to reduce convection currents in the air which so easily cause disturbances of the surface.

6. To avoid temperature differences when such exist, the test apparatus should be left for an hour before being used.

These are not difficult precautions, yet it is safe to say that a few will omit some of them and report that the oil flat is worthless.

"Use mercury instead of oil?" In reply to this question, Waland wrote, "Don't!" He tried it. Though he was able to watch the Irish boat train 15 miles away, he says, "The mercury registers every tremor." The same effect with a water flat was described by Porter in *Amateur Telescope Making*, page 60. Neither water nor mercury has much viscosity.

A hint for an experiment comes from Walter G. Thompson of Minneapolis, Minn. "Five per cent of sodium carboxyl-methyl-cellulose, obtainable from E. I. du Pont de Nemours, Inc., when added to water, will damp its surface waves by increasing the viscosity several thousand times. Proper technique is to stir the powder and water together and let the mixture set overnight. On standing, the air bubbles in the mixture will rise and burst. Warm or hot water increases the rate of solution."

DESPITE the prevalence of aluminizing for telescope mirrors, silvering is by no means extinct and probably never will be. "It is often a problem," H. Lynn Bloxom of Fort Dodge, Iowa, states, "to dry freshly silvered mirrors without leaving some trace of the dissolved matter contained in the fluid last used for rinsing. These impurities often fasten themselves to the mirror with great tenacity. When the last water rinse is followed with grain alcohol, as is often done, the results in nearly all cases approach perfection. But generous use of grain alcohol is a privilege not enjoyed by all. The drying can be done quickly by flowing over the mirror a very dilute solution of soap in distilled water. When this solution is rinsed off with pure water, the water rolls off as from a duck's back. But no hard water should be used to rinse off the soap, since this would leave a greasy precipitate."

Micrometric control of silvering is obtained by Clifford E. Lloyd of Thompson Ridge, N. Y., by the following simple method.

Instead of mixing the silvering solution and the reducing solution, the two are put in separate dishes and the mirror is dipped first in one, then in the other, and so on By this method silvering takes about 10 minutes, but can be closely watched. A larger proportion of the silver goes on the mirror and Lloyd finds the coating thicker than any he has obtained by the regular method.

Continuing on another subject, Lloyd says: "I made a mirror-grinding tool of Wood's metal, which has a melting point of about 147 degrees Fahrenheit. Thus a tool of this metal may be made by pouring it on a piece of glass of the desired curvature. However, the glass should first be warmed. A paper tape suffices to hold the metal on the glass until it has solidified."

Wood's metal consists of 50 parts bismuth, 12.5 parts cadmium, 25 parts lead, and 12.5 parts tin. The J. T. Baker Chemical Company, Phillipsburg, N. J., and the Belmont Smelting and Refining Works, Brooklyn, N. Y., are its largest manufacturers.

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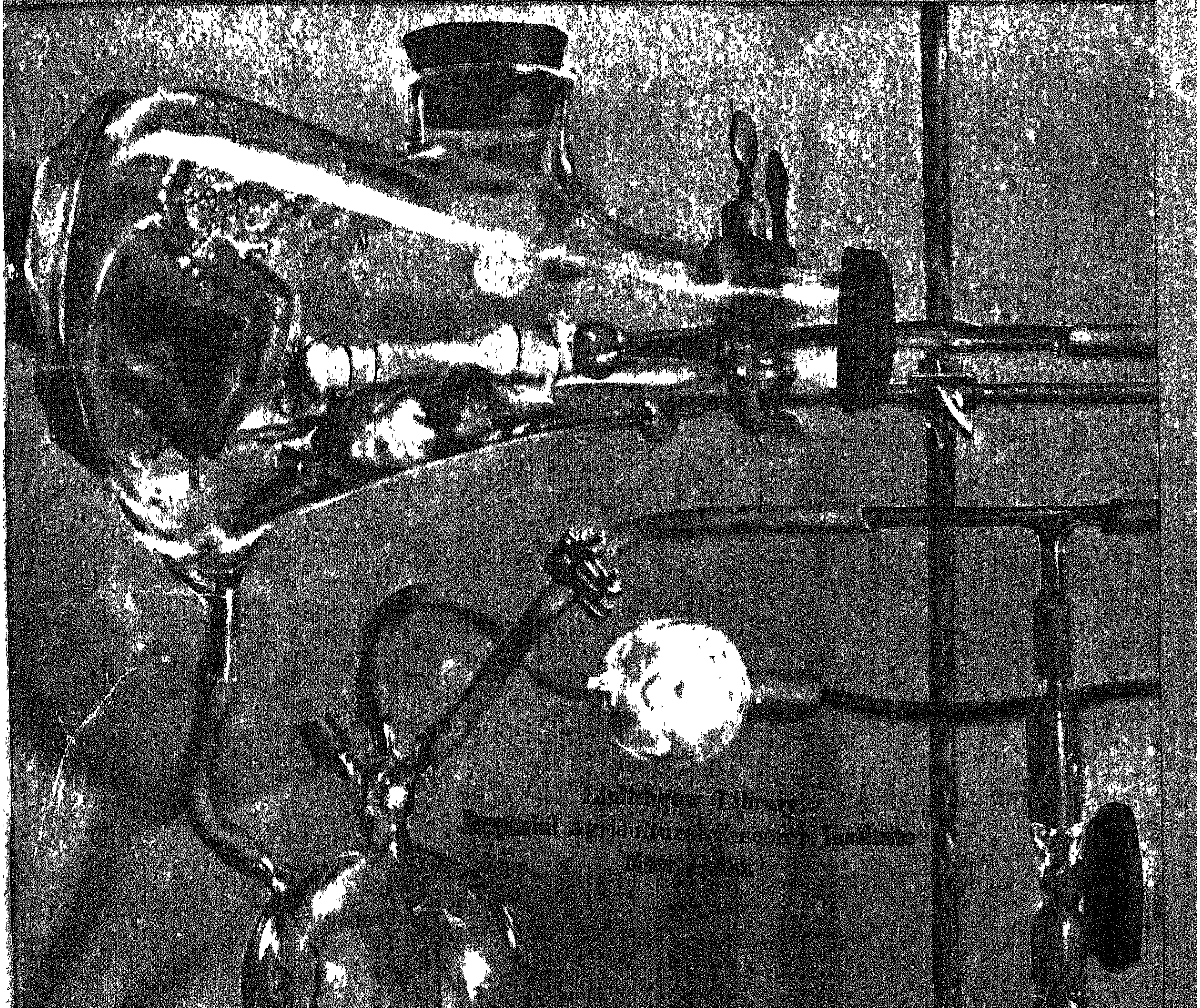

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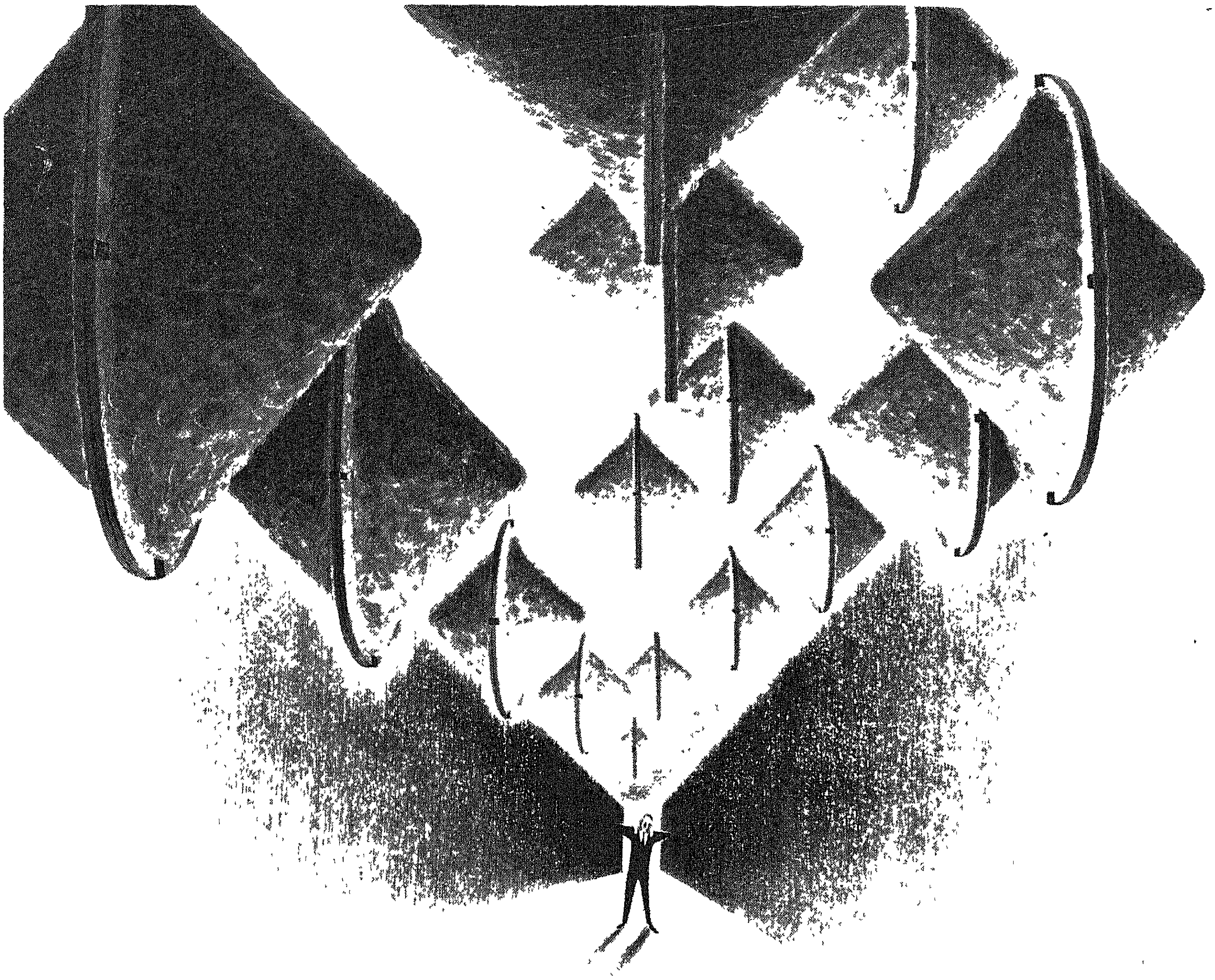

RCA scientists find way to combat noises in rooms where normal sound control methods are impractical

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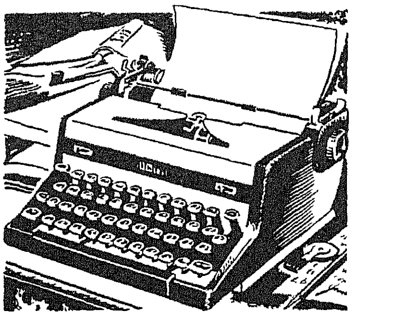
LETTERS



Sirs

I was tremendously pleased to read Dr. Brock Chisholm's article on social medicine in the April 1949 issue of the new *Scientific American* While recognizing that Dr. Chisholm covered a broad expanse of information in a very limited space, I must nevertheless comment on some omissions and assumptions in his article which if dealt with in greater detail might vitiate some of the most hopeful conclusions of his discourse.

The accident death rate in the United States is a suggestive case in point. Prevention of accidental deaths is certainly a worthy subgoal of social medicine Engineering, education and enforcement of safety measures yield striking reductions in accident death rates wherever they are conscientiously employed. Yet the over-all death rate has remained at substantially the same figure since 1913 (about 70 per 100,000 population). When traffic accidents went down, as during the war years, industrial accidents went up. I do not pretend to know why. I simply cite this case as one in which the best-intentioned practices of social medicine yielded no statistically measurable results

I must further question whether social medicine is an active or a passive agency. Dr Chisholm has by inference credited social medicine with the decline in tuberculosis rates in the United States during World War II. If we accept the idea that "tuberculosis is a social problem with a medical aspect," we must further concede that the high wartime wages paid to unskilled and semiskilled laborers (often in minority groups, such as Mexicans and Negroes) undoubtedly did more to raise their standard of living—and hence to decrease their tuberculosis death rates—than the active efforts of social medicine in terms of mass case-finding and the like. War itself was very possibly the active agent in this case and social medicine merely the counter of the tallies. This unexpected beneficial effect of war makes for difficulty in pronouncing solid social evaluations.

I cannot accept Dr. Chisholm's assumption that "humanity now has the technical 'know-how' to produce all the food the people of the world could consume" or that "we possess the technical means for making all the goods that the world's people need for decent living." I must regretfully take a stand with Dr. Chisholm's statement beyond, namely. "Poverty remains the overwhelming curse of mankind."

One cannot work toward the goals of social medicine unless he faces honestly up to the unresolved Malthusian dilemma. One need only mention the casualties of World Wars I and II—nearly 22 million lives lost, the world-wide ravage of the influenza epidemic of 1917-1918, which cost another 21 million lives, and the Russian famines of the 1920s, as well as the recurring famines in China and India, which produced untold numbers of deaths. There is nothing in this dreadful experience—or the prospect of more like it—to persuade one that the scientific and humanitarian goals of social medicine, as expressed by Dr Chisholm, are likely to be achieved.

It is pleasant to say, as Dr. Chisholm has said, "Scientific progress brings new efficiency to medicine, and social progress demands that these benefits should be made available to the whole population" and further, "We should be able to create a social organization that could permit the peoples of the world to live together effectively and peacefully." Before accepting this delightful concept of social medicine as an instrument of social progress which leads straight up like a staircase to a Kingdom of Heaven on earth, I think we must pause to ask

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whether we are walking on air or on facts

I do not question Dr. Chisholm's ideals, but I cannot altogether share his hopes for social medicine as a tool of social progress

JUSTUS J. SCHIFFERES

Health Education Council
New York, N Y.

Sirs.

In your issue of April 1949, I find a letter from Mr. Koert D. Burnham in which the writer criticizes as unfair the review in your February issue of Lincoln Barnett's *The Universe and Dr Einstein* The criticism is based on the claim that in steering readers away from the book, the review is doing a definite disservice to the cause of public understanding of scientific endeavor in this age of great specialization and compartmentalization of knowledge.

I wish to endorse *in principle* Mr. Burnham's emphasis upon the value of a bridge between the sciences and the thinking of the intelligent layman, and should not be surprised if it was Dr. Einstein's sympathy for this aim that led him to endorse the book, as he is wont to do with causes in which he sees some good It seems to me, however, that it is precisely in the treatment of the philosophical and humanistic import of the relativity theory that Mr. Barnett was at his weakest and, in fact, so weak that I regard his book as singularly unsuitable for the purposes which Mr. Burnham has in mind While it is entirely true that Mr. Barnett displayed considerable pedagogical skill in presenting the methods and results of relevant experimental work, he is obviously incompetent and irresponsible when he presents his particular philosophical interpretation as if it were integral to the theoretical framework of the relativity theory. It would seem as if that part of his book is a very poor and confused restatement of some of Eddington's and Jeans' philosophical views. In order to illustrate what I have in mind, I merely wish to mention that Einstein's relativization of space and time determinations concerns the behavior of measuring rods and natural clocks and not, as Mr. Barnett would have it, the events in the mind of the observer, who is located in the reference frame with which these rods and clocks are associated. Einstein's emphasis on the role of the observer in the determination of physical quantities cannot be construed as an assertion about mental events any more than Newton's physics can be so construed.

ADOLF GRUNBAUM

Yale University
New Haven, Conn.

50 AND 100 YEARS AGO

JULY 1899. "The serious nature of air resistance raises the question as to whether the form of all vehicles that move at high speed should not be modified so as to present the least possible resistance to the wind. This is particularly true of locomotives and cars, and it is conceivable that some light form of sheathing extending from the cars nearly to the rails, and from car to car, might materially aid in reducing the air resistance."

"The first trans-continental automobile trip will be begun on July 1. Mr. and Mrs. John D. Davis will start from *The New York Herald* building for the longest automobile run on record. Besides the length of the trip, it will be a remarkable test of American self-propelled vehicles over the worst of American roads. In Europe the longest run that has been made was 621 miles over the most perfect of roads. The trip from the Atlantic to the Pacific will cover about 3,700 miles. Mr. Davis expects to reach San Francisco early in August."

"A grand achievement has been effected by Prof. Dewar and his able assistant, Mr. Robert Lennox. These investigators, by the undoubted liquefaction of hydrogen, have put the finishing stroke on the line of research initiated by Faraday when he first reduced the gas chlorine to a liquid. The new agent of scientific research, liquid hydrogen, congeals the air surrounding the containing tube into a snow-like solid, and a piece of cork sinks to the bottom when put in the liquid, the temperature at the boiling point is 21 degrees absolute, or —252 degrees, a temperature representing a pressure which is immeasurable. The liquefaction of hydrogen is a triumph of theory as well as practice, for in face of all the enormous difficulties which have been encountered, theorists have never deviated one jot from the conviction, which sound reasoning long ago showed, that there is no such thing as a permanent gas."

"One of the American delegates to the recent Tuberculosis Congress at Berlin, who has returned, is preparing a report for the Navy Department on the work of the Congress. The chief question which now interests the profession is the preparation of an effective serum to combat the disease. The most promising work is that of Dr. Behring, one of the most celebrated of the European specialists. He is pushing on his experiments as rapidly as is consistent with careful scientific work. The development of consumption sanitariums in Europe has also attracted much interest in this country."

"M. Moissan, of the University of Paris, who has been successful in the extraction of the rare metals in the electrolytic furnace, has recently undertaken a series of experiments with the metal calcium, which, although abundantly distributed in nature in the state of carbonate, sulphate, etc., has not up to the present time been prepared in any considerable quantity in the pure state. It will be remembered that at the commencement of the century Sir Humphry Davy was the first to establish the existence in lime of a metallic body, and by decomposing it by an electric current in the presence of mercury he obtained an amalgam of the metal calcium. M. Moissan has been the first to obtain a relatively considerable weight of the pure metal."

"At present the price of the motor carriage ranges from $500 up well into the thousands. As soon as the scale of manufacture is sufficiently increased to permit the parts being made by machinery and in quantity, these prices will undoubtedly be very greatly reduced. The improvement in city conditions by the general adoption of the motor car can hardly be overestimated. Streets, clean, dustless and odorless, with light rubber-tired vehicles moving swiftly and noiselessly over their smooth expanse, would eliminate a greater part of the nervousness, distraction, and strain of modern metropolitan life."

JULY 1849. "The 710,000 tons of water which each minute pour over the precipice of Niagara are estimated to carry away a foot of the cliff every year. Taking this, and adopting the clear geological proof that the fall once existed at Queen's-town, four miles away, we must suppose a period of 20,000 years occupied in this recession of the cataract to its actual site; while the delta of the Mississippi, is nearly 14,000 square miles in extent, and estimates founded on its present rate of increase, and on calculation of the amount of earthy matter brought down the stream, have justified Mr. Lyell in alleging that 67,000 years must have elapsed since formation of this deposit began."

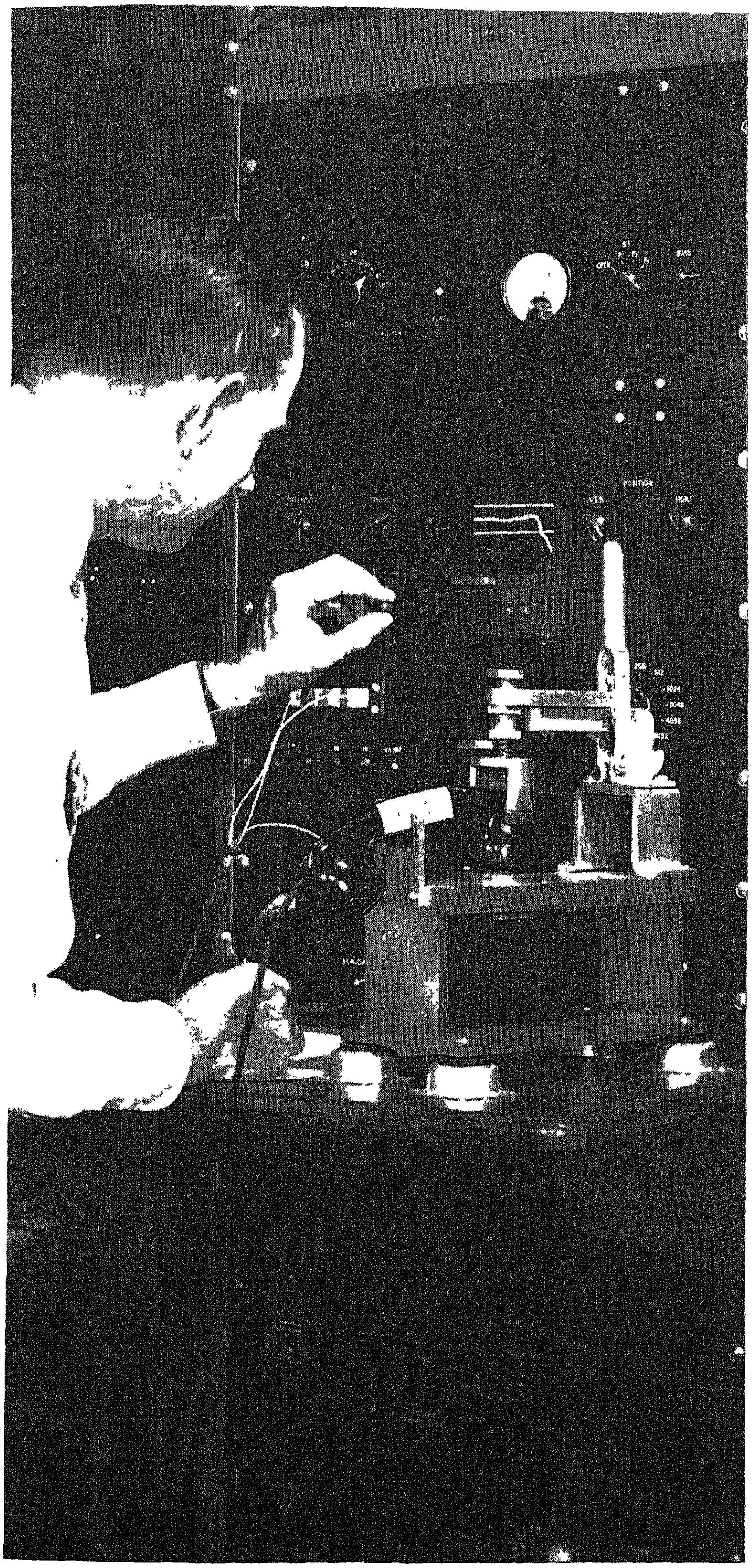
"The strongest argument against the introduction of new machines and improved machinery, is the impoverished condition of operatives in the British manufacturing districts. In England her manufacturing machinery may be said to have passed the limits of supply. It is well known that for 30 years, her manufacturing population increased at the rate of 30 per cent, while her agricultural population increased at the rate of only 1 per cent. The wars on the Continent of Europe, made her a hotbed of manufactures, and when they ceased to stimulate, it is no wonder that the forced plant suffered."

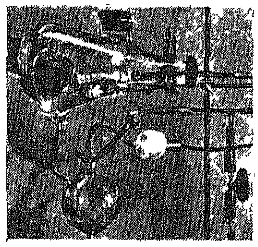
"The earthquake which destroyed Lisbon had its centre of action immediately below the city, and shook 'an arc of 700,000 square miles, equal to a twelfth part of the circumference of the globe.'"

"The first Electric Telegraph in Ireland, has recently been erected two miles long, between two railway stations at Kingsbridge."

"One of the military innovations that has marked the war in Hungary is the Austrian fire rocket. These rockets have been ably directed not only against towns, but against bodies of troops. There have also been used, both in the Austrian and Hungarian armies, probably rockets, carried by corps of foot bombardiers able to march with the infantry. Each man carries three of these small sized projectiles. Another man carries a rest framed of wood on which the rocket is placed and directed. It has been stated that these Congreves, employed in a battle, ranged by the Austrian bombardiers who have practised them for many years, have produced a tremendous effect, particularly upon the Hungarian cavalry. They are tubes of wrought iron brought to a point, pierced with holes, and filled with incendiary matter, and are so charged as to emit above them, at the end of their flight, small streams of liquid fire."

"A warmer friend of Inventors than President Taylor does not live. Amid the weighty matters pressing upon him, their interests are, in his estimation, neither the least nor the last to be looked to."





THE COVER

The painting on the cover shows part of a perfusion apparatus, in which organs may be kept alive for study apart from the organism. The yellowish tissue in the flask at the top of the painting is a beef adrenal gland. Beef blood is pumped into the gland through the tube that enters the flask from the right. Dark venous blood then flows from the bottom of the flask into the glass bulb below. Here the blood is oxygenated by air which is pumped into the bulb through the absorbent cotton filter in the center of the painting. Blood is also pumped into the bulb from the top. This is an auxiliary circuit which increases the oxygen content of all the blood in the apparatus. The left end of the flask is fitted with a rubber glove through which an experimenter pinches off a blood vessel. The apparatus was built by Oscar Hechter and N. T. Werthessen at the Worcester Foundation for Experimental Biology, which is engaged in a broad investigation of the adrenal gland. One aspect of this investigation is reported on page 44

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
16-17	David Stone Martin
18-19	Elvin A. Kabat
20-21	Mount Wilson Observatory
23	James Grunbaum (*top and bottom*), U.S. Air Force
24	James Grunbaum
30	William Auerbach-Levy
33	Eric Mose
34-35	Atomic Energy Commission
37	Eric Mose
38	E. O. Wollan and C. G. Shull
40	Ministry of Supply, United Kingdom (*top*), Wide World Photos (*bottom*)
43	U.S Army Signal Corps (*top*), Atomic Energy Commission (*bottom*)
45-47	Irving Geis
48-51	New York Public Library
53-54	Adolph Brotman
57	Smithsonian Institution
61	Robert E. Smith
62	Lyle A. Ellis
63	Russell W. Porter

What GENERAL ELECTRIC People Are Saying

T. F. PERKINSON

Manager, Transportation Engineering

LOCOMOTIVES: The phenomenal growth in the use of the diesel-electric locomotive is a growth based on sound economics. Many of the applications are such that these locomotives pay for themselves in a matter of three to five years out of savings over steam-locomotive operation. Net returns on the cost of the new motive power of 15 to 35 per cent are not uncommon.

There are approximately 9500 diesel-electric units in service on American railroads today, and of the locomotives on order with the builders at present over 95 per cent are of the diesel-electric type.

American Institute of Electric Engineers, Toledo, Ohio, May 19, 1949

★

H. A. WINNE

Vice President in Charge of Engineering Policy, Chairman of Nucleonics Committee

NUCLEAR POWER: Most people, I believe, when they think of atomic energy, visualize it as a potential source of vast amounts of industrial power—and such it ultimately may prove to be.

Atomic—or nuclear—energy will appear in the pile or nuclear reactor in the form of heat. We see no way of converting directly to electricity the energy released from the fissioning atom. So to use this energy in quantity, we must get the heat out of the pile. One way of doing this would be to pump a liquid or gas through the pile and then through a kind of steam boiler, which would then generate steam. This steam would then be used to drive a steam turbine-generator to produce electricity. In other words, as I visualize an atomic power plant, the atomic pile and some auxiliary equipment will merely replace the fuel-fired steam boiler, and from that point on the atomic plant will be the same as the one using coal or oil as a fuel.

Consequently, it seems to me that the first cost of an atomic power plant will be at least as high as that of a fuel-fired plant under normal conditions. As to operating cost, it is entirely possible that in the years to come the cost of nuclear fuel will be competitive with that of coal or oil. Today we cannot give any reliable estimate of its cost, for there are too many factors which we do not have the knowledge and experience to evaluate.

But in areas where electric power is today available readily and at reasonable cost, we must not look for any revolutionary reduction in power cost due to the advent of atomic energy. On the average the cost of fuel accounts for only 20-25 per cent of the total price paid by the consumer for fuel-generated power today, so even if we got nuclear fuel free we could expect only 20-25 per cent reduction in power costs. Of course this reduction would be tremendously significant, but not in keeping with some of the more fanciful prognostications.

On the other hand, because nuclear fuel is such an extremely concentrated source of energy, there is the very definite possibility that atomic energy may bring economical electric power to areas where the transportation costs on conventional fuel are extremely high.

However, I do not visualize small atomic power plants springing up in every isolated area. To be efficient and economical I think an atomic power plant will necessarily be of large capacity—perhaps at least a hundred thousand kilowatts—and it may require a supporting chemical plant to reclaim partly used fuel.

The picture as to where atomic central power stations may first prove economical is not at all clear, but I feel reasonably sure that it will evolve favorably as our scientists and engineers carry along their developments. We are not yet ready technically to build a 100,000-kilowatt atomic power plant, and we won't be for a long time.

Chamber of Commerce, Portland, Oregon, March 7, 1949

V. J. SCHAEFER

Research Laboratory

WEATHER RESEARCH: The energy generated in a thunderstorm is tremendous. One of the reasons for this is the fact that such a storm is inherently unstable because of the supercooled clouds which it contains. These often grow to vertical thicknesses exceeding three miles.

Such clouds when "seeded" by certain types of nuclei which form ice crystals cause the sudden release of this stored energy. Depending on the way this occurs, the subsequent developments may produce a disastrous storm or one that merely waters the countryside with a beneficial rain. It is because of this inherent unstability in many destructive storms that we may eventually exert some measure of control over them. By introducing the right type of seeding agent at the proper time, it is possible that some day we may direct these energies to serve and augment, rather than destroy and endanger, some of our other resources.

General Electric Science Forum, WGY, April 13, 1949

★

49 Years Ago

FUTURE OF LIGHTING: I personally feel, and Mr. Steinmetz endorses my views, that the electric light has a future more brilliant than its past. We should not like to assert that the carbon filament lamp is the best lamp we can have. There may be a better type of electrode for arc lamps than the carbon electrode. These things cannot be determined properly without research.

A. G. Davis, Manager Patent Department, 1900

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CONTENTS FOR JULY 1949 VOLUME 181, NUMBER 1

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

JULY 1949 VOL. 181, NO. 1

THE MATHEMATICS OF COMMUNICATION

An important new theory is based on the statistical character of language. In it the concept of entropy is closely linked with the concept of information

by Warren Weaver

HOW do men communicate, one with another? The spoken word, either direct or by telephone or radio; the written or printed word, transmitted by hand, by post, by telegraph, or in any other way—these are obvious and common forms of communication. But there are many others. A nod or a wink, a drumbeat in the jungle, a gesture pictured on a television screen, the blinking of a signal light, a bit of music that reminds one of an event in the past, puffs of smoke in the desert air, the movements and posturing in a ballet—all of these are means men use to convey ideas.

The word communication, in fact, will be used here in a very broad sense to include all of the procedures by which one mind can affect another. Although the language used will often refer specifically to the communication of speech, practically everything said applies equally to music, to pictures, to a variety of other methods of conveying information.

In communication there seem to be problems at three levels: 1) technical, 2) semantic, and 3) influential.

The technical problems are concerned with the accuracy of transference of information from sender to receiver. They are inherent in all forms of communication, whether by sets of discrete symbols (written speech), or by a varying signal (telephonic or radio transmission of voice or music), or by a varying two-dimensional pattern (television).

The semantic problems are concerned with the interpretation of meaning by the receiver, as compared with the intended meaning of the sender. This is a very deep and involved situation, even when one deals only with the relatively simple problems of communicating through speech. For example, if Mr. X is suspected not to understand what Mr. Y says, then it is not possible, by having Mr. Y do nothing but talk further with Mr. X, completely to clarify this situation in any finite time. If Mr. Y says "Do you now understand me?" and Mr. X says "Certainly I do," this is not necessarily a certification that understanding has been achieved. It may just be that Mr. X did not understand the question. If this sounds silly, try it again as "Czy pan mnie rozumie?" with the answer "Hai wakkate imasu." In the restricted field of speech communication, the difficulty may be reduced to a tolerable size, but never completely eliminated, by "explanations." They are presumably never more than approximations to the ideas being explained, but are understandable when phrased in language that has previously been made reasonably clear by usage. For example, it does not take long to make the symbol for "yes" in any language understandable.

The problems of influence or effectiveness are concerned with the success with which the meaning conveyed to the receiver leads to the desired conduct on his part. It may seem at first glance undesirably narrow to imply that the purpose of all communication is to influence the conduct of the receiver. But with any reasonably broad definition of conduct, it is clear that communication either affects conduct or is without any discernible and provable effect at all.

One might be inclined to think that the technical problems involve only the engineering details of good design of a communication system, while the semantic and the effectiveness problems contain most if not all of the philosophical content of the general problem of communication. To see that this is not the case, we must now examine some important recent work in the mathematical theory of communication.

THIS is by no means a wholly new theory. As the mathematician John von Neumann has pointed out, the 19th-century Austrian physicist Ludwig Boltzmann suggested that some concepts of statistical mechanics were applicable to the concept of information Other scientists, notably Norbert Wiener of the Massachusetts Institute of Technology, have made profound contributions. The work which will be here reported is that of Claude Shannon of the Bell Telephone Laboratories, which was preceded by that of H. Nyquist and R. V. L. Hartley in the same organization. This work applies in the first instance only to the technical problem, but the theory has broader significance. To begin with, meaning and effectiveness are inevitably restricted by the theoretical limits of accuracy in symbol transmission. Even more significant, a theoretical analysis of the technical problem reveals that it overlaps the semantic and the effectiveness problems more than one might suspect.

A communication system is symbolically represented in the drawing on pages 12 and 13. The information source selects a desired message out of a set of possible messages. (As will be shown, this is a particularly important func-

tion.) The transmitter changes this message into a signal which is sent over the communication channel to the receiver.

The receiver is a sort of inverse transmitter, changing the transmitted signal back into a message, and handing this message on to the destination. When I talk to you, my brain is the information source, yours the destination, my vocal system is the transmitter, and your ear with the eighth nerve is the receiver.

In the process of transmitting the signal, it is unfortunately characteristic that certain things not intended by the information source are added to the signal. These unwanted additions may be distortions of sound (in telephony, for example), or static (in radio), or distortions in the shape or shading of a picture (television), or errors in transmission (telegraphy or facsimile). All these changes in the signal may be called noise.

The questions to be studied in a communication system have to do with the amount of information, the capacity of the communication channel, the coding process that may be used to change a message into a signal and the effects of noise.

First off, we have to be clear about the rather strange way in which, in this theory, the word "information" is used; for it has a special sense which, among other things, must not be confused at all with meaning. It is surprising but true that, from the present viewpoint, two messages, one heavily loaded with meaning and the other pure nonsense, can be equivalent as regards information.

In fact, in this new theory the word information relates not so much to what you *do* say, as to what you *could* say. That is, information is a measure of your freedom of choice when you select a message. If you are confronted with a very elementary situation where you have to choose one of two alternative messages, then it is arbitrarily said that the information associated with this situation is unity. The concept of information applies not to the individual messages, as the concept of meaning would, but rather to the situation as a whole, the unit information indicating that in this situation one has an amount of freedom of choice, in selecting a message, which it is convenient to regard as a standard or unit amount. The two messages between which one must choose in such a selection can be anything one likes. One might be the King James version of the Bible, and the other might be "Yes."

THE remarks thus far relate to artificially simple situations where the information source is free to choose only among several definite messages—like a man picking out one of a set of standard birthday-greeting telegrams. A more natural and more important situation is that in which the information source makes a sequence of choices from some set of elementary symbols, the selected sequence then forming the message. Thus a man may pick out one word after another, these individually selected words then adding up to the message.

Obviously probability plays a major role in the generation of the message, and the choices of the successive symbols depend upon the preceding choices. Thus, if we are concerned with English speech, and if the last symbol chosen is "the," then the probability that the next word will be an article, or a verb form other than a verbal, is very small. After the three words "in the event," the probability for "that" as the next word is fairly high, and for "elephant" as the next word is very low. Similarly, the probability is low for such a sequence of words as "Constantinople fishing nasty pink." Incidentally, it is low, but not zero, for it is perfectly possible to think of a passage in which one sentence closes with "Constantinople fishing," and the next begins with "Nasty pink." (We might observe in passing that the sequence under discussion *has* occurred in a single good English sentence, namely the one second preceding.)

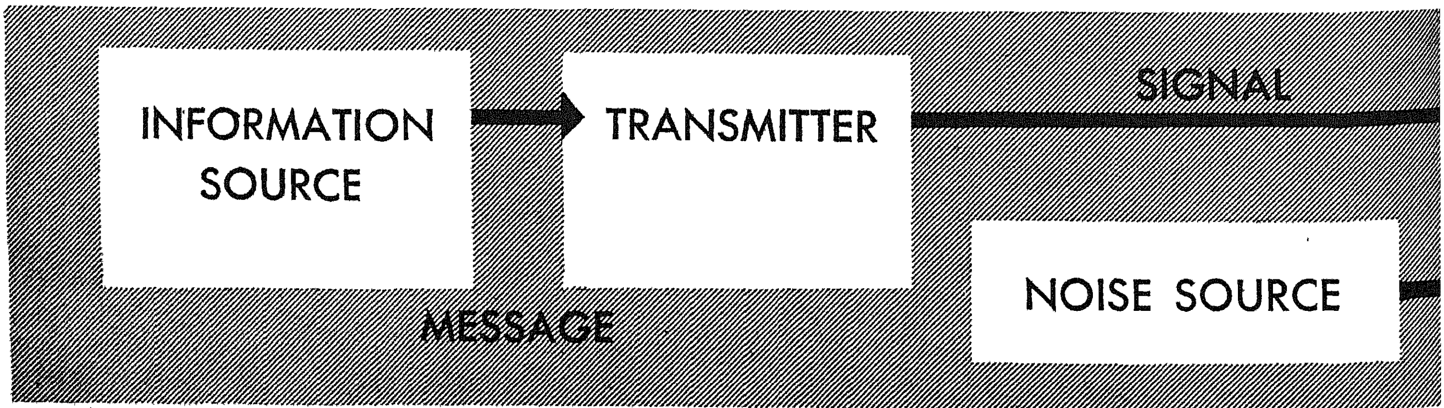
As a matter of fact, Shannon has shown that when letters or words chosen at random are set down in sequences dictated by probability considerations alone, they tend to arrange themselves in meaningful words and phrases (*see illustration on page 15*).

Now let us return to the idea of information. The quantity which uniquely meets the natural requirements that one sets up for a measure of information turns out to be exactly that which is known in thermodynamics as entropy, or the degree of randomness, or of "shuffledness" if you will, in a situation. It is expressed in terms of the various probabilities involved.

To those who have studied the physical sciences, it is most significant that an entropy-like expression appears in communication theory as a measure of information. The concept of entropy, introduced by the German physicist Rudolf Clausius nearly 100 years ago, closely associated with the name of Boltzmann, and given deep meaning by Willard Gibbs of Yale in his classic work on statistical mechanics, has become so basic and pervasive a concept that Sir Arthur Eddington remarked: "The law that entropy always increases—the second law of thermodynamics—holds, I think, the supreme position among the laws of Nature."

Thus when one meets the concept of entropy in communication theory, he has a right to be rather excited. That information should be measured by entropy is, after all, natural when we remember that information is associated with the amount of freedom of choice we have in constructing messages. Thus one can say of a communication source, just as he would also say of a thermodynamic ensemble: "This situation is highly organized; it is not characterized by a large degree of randomness or of choice—that is to say, the information, or the entropy, is low."

We must keep in mind that in the mathematical theory of communication we are concerned not with the meaning of individual messages but with the whole statistical nature of the information source. Thus one is not surprised that the capacity of a channel of communication is to be described in terms of the amount of information it can



A COMMUNICATION SYSTEM may be reduced to these fundamental elements. In telephony the signal is a varying electric current, and the channel is a wire. In speech the signal is varying sound pressure, and the

transmit, or better, in terms of its ability to transmit what is produced out of a source of a given information.

The transmitter may take a written message and use some code to encipher this message into, say, a sequence of numbers, these numbers then being sent over the channel as the signal. Thus one says, in general, that the function of the transmitter is to encode, and that of the receiver to decode, the message. The theory provides for very sophisticated transmitters and receivers—such, for example, as possess "memories," so that the way they encode a certain symbol of the message depends not only upon this one symbol but also upon previous symbols of the message and the way they have been encoded.

We are now in a position to state the fundamental theorem for a noiseless channel transmitting discrete symbols. This theorem relates to a communication channel which has a capacity of C units per second, accepting signals from an information source of H units per second. The theorem states that by devising proper coding procedures for the transmitter it is possible to transmit symbols over the channel at an average rate which is nearly C/H, but which, no matter how clever the coding, can never be made to exceed C/H.

VIEWED superficially, say in rough analogy to the use of transformers to match impedances in electrical circuits, it seems very natural, although certainly pretty neat, to have this theorem which says that efficient coding is that which matches the statistical characteristics of information source and channel. But when it is examined in detail for any one of the vast array of situations to which this result applies, one realizes how deep and powerful this theory is.

How does noise affect information? Information, we must steadily remember, is a measure of one's freedom of choice in selecting a message. The greater this freedom of choice, the greater is the uncertainty that the message actually selected is some particular one. Thus greater freedom of choice, greater uncertainty and greater information all go hand in hand.

If noise is introduced, then the received message contains certain distortions, certain errors, certain extraneous material, that would certainly lead to increased uncertainty. But if the uncertainty is increased, the information is increased, and this sounds as though the noise were beneficial!

It is true that when there is noise, the received signal is selected out of a more varied set of signals than was intended by the sender. This situation beautifully illustrates the semantic trap into which one can fall if he does not remember that "information" is used here with a special meaning that measures freedom of choice and hence uncertainty as to what choice has been made. Uncertainty that arises by virtue of freedom of choice on the part of the sender is desirable uncertainty. Uncertainty that arises because of errors or because of the influence of noise is undesirable uncertainty. To get the useful information in the received signal we must subtract the spurious portion. This is accomplished, in the theory, by establishing a quantity known as the "equivocation," meaning the amount of ambiguity introduced by noise. One then refines or extends the previous definition of the capacity of a noiseless channel, and states that the capacity of a noisy channel is defined to be equal to the maximum rate at which useful information (*i.e.*, total uncertainty minus noise uncertainty) can be transmitted over the channel.

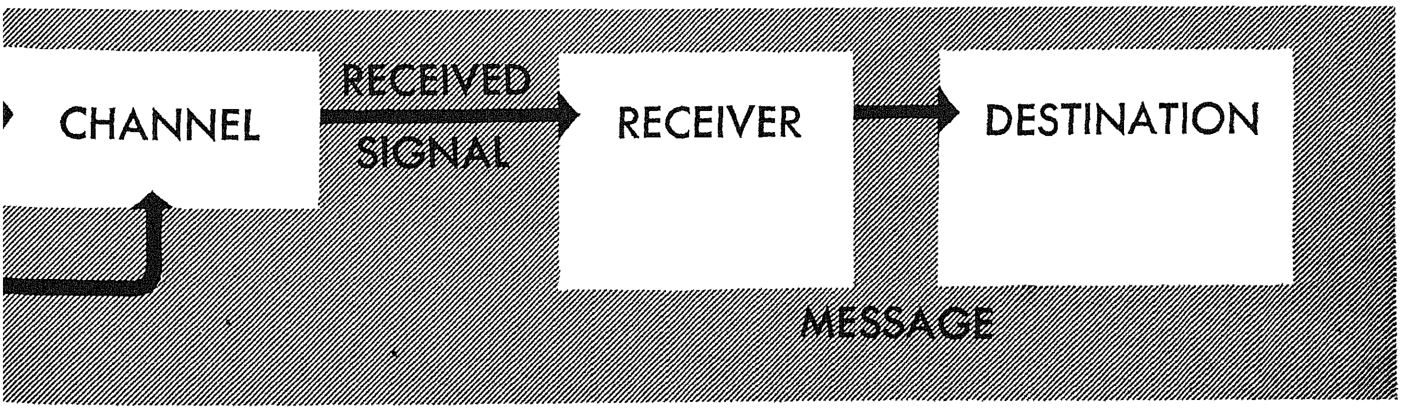
Now, finally, we can state the great central theorem of this whole communication theory. Suppose a noisy channel of capacity C is accepting information from a source of entropy H, entropy corresponding to the number of possible messages from the source. If the channel capacity C is equal to or larger than H, then by devising appropriate coding systems the output of the source can be transmitted over the channel with as little error as one pleases. But if the channel capacity C is less than H, the entropy of the source, then it is impossible to devise codes which reduce the error frequency as low as one may please.

However clever one is with the coding process, it will always be true that after the signal is received there remains some undesirable uncertainty about what the message was; and this undesirable uncertainty—this noise or equivocation—will always be equal to or greater than H minus C. But there is always at least one code capable of reducing this undesirable uncertainty down to a value that exceeds H minus C by a small amount.

This powerful theorem gives a precise and almost startlingly simple description of the utmost dependability one can ever obtain from a communication channel which operates in the presence of noise. One must think a long time, and consider many applications, before he fully realizes how powerful and general this amazingly compact theorem really is. One single application can be indicated here, but in order to do so, we must go back for a moment to the idea of the information of a source.

Having calculated the entropy (or the information, or the freedom of choice) of a certain information source, one can compare it to the maximum value this entropy could have, subject only to the condition that the source continue to employ the same symbols. The ratio of the actual to the maximum entropy is called the relative entropy of the source. If the relative entropy of a certain source is, say, eight-tenths, this means roughly that this source is, in its choice of symbols to form a message, about 80 per cent as free as it could possibly be with these same symbols. One minus the relative entropy is called the "redundancy." That is to say, this fraction of the message is unnecessary in the sense that if it were missing the message would still be essentially complete, or at least could be completed.

It is most interesting to note that the redundancy of English is just about 50 per cent. In other words, about half of the letters or words we choose in writing or speaking are under our free choice,



channel the air. Frequently things not intended by the information source are impressed on the signal. The static of radio is one example; distortion in telephony is another. All these additions may be called noise.

and about half are really controlled by the statistical structure of the language, although we are not ordinarily aware of it. Incidentally, this is just about the minimum of freedom (or relative entropy) in the choice of letters that one must have to be able to construct satisfactory crossword puzzles In a language that had only 20 per cent of freedom, or 80 per cent redundancy, it would be impossible to construct crossword puzzles in sufficient complexity and number to make the game popular.

Now since English is about 50 per cent redundant, it would be possible to save about one-half the time of ordinary telegraphy by a proper encoding process, provided one transmitted over a noiseless channel. When there is noise on a channel, however, there is some real advantage in not using a coding process that eliminates all of the redundancy. For the remaining redundancy helps combat the noise. It is the high redundancy of English, for example, that makes it easy to correct errors in spelling that have arisen during transmission.

THE communication systems dealt with so far involve the use of a discrete set of symbols—say letters—only moderately numerous. One might well expect that the theory would become almost indefinitely more complicated when it seeks to deal with continuous messages such as those of the speaking voice, with its continuous variation of pitch and energy As is often the case, however, a very interesting mathematical theorem comes to the rescue As a practical matter, one is always interested in a continuous signal which is built up of simple harmonic constituents, not of all frequencies but only of those that lie wholly within a band from zero to, say, W cycles per second. Thus very satisfactory communication can be achieved over a telephone channel that handles frequencies up to about 4,000, although the human voice does contain higher frequencies. With frequencies up to 10,000 or 12,000, high-fidelity radio transmission of symphonic music is possible.

The theorem that helps us is one which states that a continuous signal, T seconds in duration and band-limited in frequency to the range from zero to W, can be completely specified by stating 2TW numbers. This is really a remarkable theorem. Ordinarily a continuous curve can be defined only approximately by a finite number of points. But if the curve is built up out of simple harmonic constituents of a limited number of frequencies, as a complex sound is built up out of a limited number of pure tones, then a finite number of quantities is all that is necessary to define the curve completely.

Thanks partly to this theorem, and partly to the essential nature of the situation, it turns out that the extended theory of continuous communication is somewhat more difficult and complicated mathematically, but not essentially different from the theory for discrete symbols. Many of the statements for the discrete case require no modification for the continuous case, and others require only minor change

The mathematical theory of communication is so general that one does not need to say what kinds of symbols are being considered—whether written letters or words, or musical notes, or spoken words, or symphonic music, or pictures. The relationships it reveals apply to all these and to other forms of communication. The theory is so imaginatively motivated that it deals with the real inner core of the communication problem.

One evidence of its generality is that the theory contributes importantly to, and in fact is really the basic theory of, cryptography, which is of course a form of coding. In a similar way, the theory contributes to the problem of translation from one language to another, although the complete story here clearly requires consideration of meaning, as well as of information Similarly, the ideas developed in this work connect so closely with the problem of the logical design of computing machines that it is no surprise that Shannon has written a paper on the design of a computer that would be capable of playing a skillful game of chess. And it is of further pertinence to the present contention that his paper closes with the remark that either one must say that such a computer "thinks," or one must substantially modify the conventional implication of the verb "to think"

> EDITOR'S NOTE
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> The University of Illinois Press will shortly publish a memoir on communication theory. This will contain the original mathematical articles on communication by Claude E. Shannon of the Bell Telephone Laboratories, together with an expanded and slightly more technical version of Dr. Weaver's article.

The theory goes further. Though ostensibly applicable only to problems at the technical level, it is helpful and suggestive at the levels of semantics and effectiveness as well. The formal diagram of a communication system on pages 12 and 13 can, in all likelihood, be extended to include the central issues of meaning and effectiveness.

Thus when one moves to those levels it may prove to be essential to take account of the statistical characteristics of the destination. One can imagine, as an addition to the diagram, another box labeled "Semantic Receiver" interposed between the engineering receiver (which changes signals to messages) and the destination. This semantic receiver subjects the message to a second decoding, the demand on this one being that it must match the statistical semantic characteristics of the message to the statistical semantic capacities of the totality of receivers, or of that subset of receivers which constitutes the audience one wishes to affect

Similarly one can imagine another box in the diagram which, inserted between the information source and the transmitter, would be labeled "Semantic Noise" (not to be confused with "engineering noise"). This would represent distortions of meaning introduced by the information source, such as a speaker, which are not intentional but nevertheless affect the destination, or listener. And the problem of semantic decoding must take this semantic noise into account. It is also possible to think of a treatment or adjustment of the original message that would make the sum of message meaning plus semantic noise equal to the desired total message meaning at the destination.

ANOTHER way in which the theory can be helpful in improving communication is suggested by the fact that error and confusion arise and fidelity decreases when, no matter how good the coding, one tries to crowd too much over a channel. A general theory at all levels will surely have to take into account not only the capacity of the channel but also (even the words are right!) the capacity of the audience. If you overcrowd the capacity of the audience, it is probably true, by direct analogy, that you do not fill the audience up and then waste only the remainder by spilling More likely, and again by direct analogy, you force a general error and confusion.

The concept of information developed in this theory at first seems disappointing and bizarre—disappointing because it has nothing to do with meaning, and bizarre because it deals not with a single message but rather with the statistical character of a whole ensemble of messages, bizarre also because in these statistical terms the words information and uncertainty find themselves partners.

But we have seen upon further examination of the theory that this analysis has so penetratingly cleared the air that one is now perhaps for the first time ready for a real theory of meaning. An engineering communication theory is just like a very proper and discreet girl at the telegraph office accepting your telegram. She pays no attention to the meaning, whether it be sad or joyous or embarrassing. But she must be prepared to deal intelligently with all messages that come to her desk. This idea that a communication system ought to try to deal with all possible messages, and that the intelligent way to try is to

base design on the statistical character of the source, is surely not without significance for communication in general. Language must be designed, or developed, with a view to the totality of things that man may wish to say; but not being able to accomplish everything, it should do as well as possible as often as possible. That is to say, it too should deal with its task statistically.

This study reveals facts about the statistical structure of the English language, as an example, which must seem significant to students of every phase of language and communication. It suggests, as a particularly promising lead, the application of probability theory to semantic studies Especially pertinent is the powerful body of probability theory dealing with what mathematicians call the Markoff processes, whereby past events influence present probabilities, since this theory is specifically adapted to handle one of the most significant but difficult aspects of meaning, namely the influence of context. One has the vague feeling that information and meaning may prove to be something like a pair of canonically conjugate variables in quantum theory, that is, that information and meaning may be subject to some joint restriction that compels the sacrifice of one if you insist on having much of the other.

Or perhaps meaning may be shown to be analogous to one of the quantities on which the entropy of a thermodynamic ensemble depends. Here Eddington has another apt comment.

"Suppose that we were asked to arrange the following in two categories—*distance, mass, electric force, entropy, beauty, melody*.

"I think there are the strongest grounds for placing entropy alongside beauty and melody, and not with the first three. Entropy is only found when the parts are viewed in association, and it is by viewing or hearing the parts in association that beauty and melody are discerned. All three are features of arrangement. It is a pregnant thought that one of these three associates should be able to figure as a commonplace quantity of science. The reason why this stranger can pass itself off among the aborigines of the physical world is that it is able to speak their language, *viz.*, the language of arithmetic."

One feels sure that Eddington would have been willing to include the word meaning along with beauty and melody; and one suspects he would have been thrilled to see, in this theory, that entropy not only speaks the language of arithmetic; it also speaks the language of language.

Warren Weaver is Director for the Natural Sciences in the Rockefeller Foundation.

1. Zero-order approximation

XFOML RXKHRJFFJUJ ZLPWCFWKCYJ FFJEYVKCQSGXYD QPAAMKBZAACIBZLHJQD

2. First-order approximation

OCRO HLI RGWR NMIELWIS EU LL NBNESEBYA TH EEI ALHENHTTPA OOBTTVA NAH BRL

3. Second-order approximation

ON IE ANTSOUTINYS ARE T INCTORE ST BE S DEAMY ACHIN D ILONASIVE TUCOOWE AT TEASONARE FUSO TIZIN ANDY TOBE SEACE CTISBE

4. Third-order approximation

IN NO IST LAT WHEY CRATICT FROURE BIRS GROCID PONDENOME OF DEMONSTURES OF THE REPTAGIN IS REGOACTIONA OF CRE

5. First-Order Word Approximation

REPRESENTING AND SPEEDILY IS AN GOOD APT OR COME CAN DIFFERENT NATURAL HERE HE THE A IN CAME THE TO OF TO EXPERT GRAY COME TO FURNISHES THE LINE MESSAGE HAD BE THESE.

6. Second-Order Word Approximation

THE HEAD AND IN FRONTAL ATTACK ON AN ENGLISH WRITER THAT THE CHARACTER OF THIS POINT IS THEREFORE ANOTHER METHOD FOR THE LETTERS THAT THE TIME OF WHO EVER TOLD THE PROBLEM FOR AN UNEXPECTED

ARTIFICIAL LANGUAGE results when letters or words are set down statistically. 1. Twenty-six letters and one space are chosen at random. 2. Letters are chosen according to their frequency in English. 3. Letters are chosen according to the frequency with which they follow other letters. 4. Letters are chosen according to frequency with which they follow two other letters. Remaining examples do the same with words instead of letters.

ALLERGIC MECHANISMS IN NERVOUS DISEASE

When monkeys are injected with their own brain tissue they develop neurological disorders. This remarkable fact raises the question of whether a similar process may occur in man

by Elvin A. Kabat

THE PASTEUR treatment for rabies, a series of inoculations of rabbits' spinal cord tissue containing weakened rabies virus, was first used on a large scale at the end of the last century. The treatment occasionally produced a peculiar aftereffect. A small proportion of the people who were inoculated developed a paralytic disease of the nervous system which was sometimes followed by complete recovery but was also known to result in permanent disability or death. The pathological changes observed following anti-rabies treatment were limited to the central nervous system. There were small scattered patches of inflammation, and the myelin sheaths covering the nerve fibers in these areas disintegrated.

The cause of the disease was difficult to understand. The Pasteur treatment involved the use of rabbit spinal cord containing rabies virus which, although still alive, had been attenuated or reduced in virulence by drying for varying periods of time. The hypothesis that the inflammation, or encephalomyelitis, was an atypical effect of the virus was unsatisfactory, chiefly because the pathology differed considerably from that observed in rabies or in various other virus infections of the nervous system. It had been observed that a somewhat similar disease called acute disseminated encephalomyelitis occasionally occurred following smallpox vaccination and after a variety of diseases such as measles and scarlet fever Furthermore, in more recent rabies vaccines the virus is not simply attenuated but is actually killed, usually with carbolic acid; these vaccines still give rise to encephalomyelitis in about one of every 5,000 rabies inoculations. Since the hypothesis that rabies virus produced encephalomyelitis was no longer tenable, it became necessary to look for other evidence to explain the occurrence of the disease.

Some 14 years ago at the Rockefeller Institute for Medical Research T. M. Rivers and his co-workers D. H. Sprunt, G. P. Berry and F. F. Schwentker decided to study the other constituent of rabies vaccine—rabbit central nervous tissue. They injected monkeys with emulsions of normal rabbit brain in an effort to determine whether this material was of importance in causing the pathological changes. After a large number of injections and over time intervals as long as 15 months, a number of their monkeys developed a variety of symptoms including unsteadiness of gait, rotation of the head, weakness of facial muscles, blindness and other signs of disease of the central nervous system. The cerebrospinal fluid of the monkeys showed increases in protein content and in the number of white cells. Post-mortem examination revealed lesions in the central nervous system similar in many respects to those of acute disseminated encephalomyelitis in man.

Rivers and his co-workers carried out thorough bacteriological studies and inoculated a variety of animals with the brain tissue of these monkeys to exclude the possibility that some accidentally introduced bacterium or virus had caused the disease. No evidence indicating the presence of such an infectious agent was found. These studies were confirmed several years later by A. Ferraro and G. A. Jervis at the New York State Psychiatric Institute.

So it appeared that the injection of normal rabbit brain tissue alone into

SYMPTOMS of acute disseminated encephalomyelitis are shown in these drawings. At left is impairment of motorability, demonstrated by a monkey's inability to grasp a finger. Second from left is truncal ataxia, in

monkeys could produce acute disseminated encephalomyelitis. This suggested that the most likely cause of the encephalomyelitis that followed vaccination against rabies was the rabbit spinal cord tissue in the vaccine

A hypothesis to explain how this might occur readily suggested itself The injected foreign tissue stimulates the formation of antibodies in the host. These may pass through the circulation, ooze out of the capillaries of the central nervous system and react with nerve tissues to produce the disease. Thus the mechanism would involve immunological or allergic factors. In the usual form of allergy, contact with a foreign substance, *e.g.*, ragweed pollen, stimulates the formation of antibodies On subsequent exposure of the individual to the same substance, the foreign material reacts with the antibodies and initiates a chain of chemical events leading to symptoms such as hay fever or asthma.

The mechanism suggested for encephalomyelitis also has certain similarities to that involved in erythroblastosis fetalis, or Rh disease. A woman who originally lacks the Rh factor in her blood may produce antibodies to this factor if it is introduced by a transfusion with Rh-positive cells or during a pregnancy. In that event she may have difficulty in subsequent pregnancies. If the fetus is Rh-positive, the mother's anti-Rh antibodies may pass through the placenta into the baby's circulation and react with its Rh-positive cells, destroying them and producing erythroblastosis fetalis.

The novel feature of the hypothesis that postulates an allergic reaction to explain the encephalomyelitis after injection of materials containing brain or spinal cord tissue is the assumption that the antibodies which are formed to attack the injected brain tissue also react with the tissues of the individual's own central nervous system. While the hypothesis apparently accounted fairly satisfactorily for encephalomyelitis following anti-rabies inoculations, it did not explain how acute disseminated encephalomyelitis could follow measles or smallpox vaccination where no introduction of foreign brain tissue was involved. However, it stimulated the speculation that in these cases some substance in the individual's own central nervous system might in some unknown manner induce the formation of antibodies to itself. If such a mechanism could be established experimentally, it would be of general biological importance in the understanding of the pathology of many human diseases. Multiple sclerosis, a progressive disease of the central nervous system for which no adequate treatment is known, exhibits many similarities to acute disseminated encephalomyelitis, indeed, many investigators believe them to be different forms of the same disease, multiple sclerosis being a more chronic or more slowly progressing form. Other diseases, such as rheumatic fever, glomerulonephritis (inflammation of the blood vessels of the kidney) and the toxemias of pregnancy, are believed by many to have a similar allergic basis

In the case of glomerulonephritis, the Japanese scientist M Masugi, J. E. Smadel of the Rockefeller Institute and others observed that if ducks or rabbits received injections of rat kidney, they developed antibodies to the rat kidney. When serum from these immunized rabbits containing the rat-kidney antibodies was injected into rats, it gave rise to typical glomerulonephritis, with marked albumin excretion in the urine and increases in the nonprotein nitrogen of the blood.

THE experimental production of disseminated encephalomyelitis in the monkey offered a means of further investigating the disease mechanism. Unfortunately the large numbers of injections and long time-intervals required to produce the disease still imposed formidable difficulties, and for the next 10 years little further progress was made. During this fallow period, however, a notable advance was made in methods of stimulating the production of antibodies Jules Freund and his co-workers (now at the Public Health Research Institute of the City of New York) found that antibody formation could be increased greatly by administering the antigens that produced them in the form of an emulsion with paraffin oil, using a lanolinlike substance as an emulsifying agent. In certain cases, the inclusion of killed tubercle bacilli had an additional enhancing effect. The substances used—paraffin oil, killed tubercle bacilli and the lanolinlike emulsifying agent—are called adjuvants.

At the end of the war, our laboratory at the Columbia University College of Physicians and Surgeons and at the Neurological Institute of New York was beginning to take up the threads of research on demyelinating disease which had been dropped for more pressing war work in 1941. With Abner Wolf and Ada E. Bezer, the author decided to try the Freund adjuvants with brain tissue in an effort to produce encephalomyelitis in monkeys more readily. The first experiment was spectacularly successful. Three of four monkeys injected with an emulsion of normal rabbit brain, Aquaphor (a proprietary lanolinlike emulsifying agent), paraffin oil and dead tubercle bacilli developed the disease after only three injections, all three animals were stricken within 40 days after the start of the experiment. A control group of animals injected with normal rabbit tissue of the lung instead of the brain, plus adjuvants, remained perfectly healthy. Further experiments showed that the brain tissue not only of rabbits but also

which a monkey is unable to maintain its balance. Third is head tremor. Fourth is intentional ataxia, in which a monkey cannot bring an object to its mouth. Fifth is strabismus, in which eyes turn outward. Last is blindness.

of monkeys produced the disease, in other words the test monkeys were allergic to tissue of their own species

At about this time we learned that identical results had been obtained by Isabel Morgan at Johns Hopkins University, working completely independently and from a somewhat different approach. Dr Morgan was interested in obtaining an enhanced antibody response to poliomyelitis virus in monkeys by the adjuvant technique. She used infected monkey spinal cord as the source of the virus Her monkeys developed acute disseminated encephalomyelitis. Dr. Morgan rapidly established that the same results could be obtained with normal uninfected spinal cord.

These studies have since been confirmed in many laboratories in this country and abroad. Freund, E R. Stern and T. M. Pisani were able to produce an *encephalomyelitis* in guinea pigs by using guinea-pig or rabbit brain emulsions with adjuvants L. R. Morrison of the Harvard Medical School and the Massachusetts General Hospital obtained a similar disease in rabbits by means of injections of rabbit spinal cord. Pathological changes in the guinea pig and rabbit do not show as striking a resemblance to human demyelinating diseases as do changes observed in the monkey. Indeed, some workers believe that if the monkey disease had not provided a link, the relationship of the rabbit and guinea-pig conditions to the human disease would not have been readily apparent.

THE effect of adjuvants in enhancing the rate at which the disease is produced provides further support for the hypothesis that an immunological mechanism is involved. Additional evidence can be inferred from pathological studies. According to the hypothesis, antibodies formed as a reaction to injected brain tissue pass through the circulation and then seep out of the capillaries. If this concept is correct, the first place where the antibodies come in contact with the individual's central nervous tissue should be around the capillaries and blood vessels, and the typical small lesions should always be found near these tissues. This corresponds precisely with the actual pathological findings.

Although tissues from one monkey had been used to produce encephalomyelitis in other monkeys, the possibility could not be ignored that the central nervous tissues of individuals of the same species differed and that the disease was still a response to "foreign" tissue. This is a crucial issue, because no animal is likely to "contact" the brain material of another animal. Unless it could be shown that an animal may develop an allergy to its own nervous tissue, the hypothesis could not account for the observed incidence of encephalomyelitis in instances where no contact with foreign brain tissue is involved. It was possible to examine this problem experimentally

The question was· Could an animal be given the disease by injections of tissue from *its own brain*? Under aseptic conditions, the right frontal lobe of the brain was removed surgically from each of six normal monkeys. When the animals recovered from the effects of the operation, each received a series of three injections of an emulsion with adjuvants prepared from its own brain tissue Five of the six animals came down with typical acute disseminated encephalomyelitis!

The working hypothesis that an antibody is involved is by no means completely proved. If such an antibody were present in sufficient quantity in the blood, it should be possible to produce the disease by injecting blood serum from animals with encephalomyelitis into healthy monkeys. To date all efforts to do this have failed. The failure does not disprove the hypothesis, however, since it is not unlikely that the central nervous system of the diseased monkey removes antibodies from the blood almost as fast as they are formed.

Another hypothesis, advanced by Freund, asserts that the allergic reaction in this disease is similar to that observed in the tuberculin test for tuberculosis—a form of hypersensitivity not associated with a circulating antibody. In other instances of this type of sensitivity, Merrill Chase of the Rockefeller Institute has demonstrated that cell exudates or suspensions of tissue cells from allergic animals can transfer the sensitivity to healthy animals. However, this type of experiment—transfer of cell exudates and suspensions from the spleen and lymph tissues of diseased monkeys—failed to produce encephalomyelitis in monkeys.

Another phase of our studies involves the question of how the postulated antibodies are produced in reaction to the injected brain tissue. Some suggestive evidence has been obtained. Freund observed in guinea pigs, and we subsequently found in monkeys, that an adjuvant mixture which omitted dead tubercle bacilli produced no encephalomyelitis in a series of three injections. The question arose as to how the dead tubercle bacilli exerted their enhancing effect. It has long been known that dead tubercle bacilli produce a generalized body reaction when injected into animals with focal tuberculous infections, and that peculiar sensitivities also sometimes develop. Was encephalomyelitis initiated by this systemic effect of the tubercle bacillus? If so, it should be possible to produce the disease by injecting the tubercle bacilli at a site removed from the injection of the brain tissue. Accordingly each of a group of monkeys was injected in one arm with an emulsion of monkey brain, paraffin oil, and the emulsifying agent Aquaphor (but no tubercle bacilli), and in the other arm with an emulsion of tubercle bacilli, paraffin oil and Aquaphor (but no brain). These animals failed to develop the disease, a finding which suggests that the bacilli must be present at the same site as the brain tissue for the enhancing effect of the adjuvants to occur.

PERHAPS the most important question to be settled is the chemical nature of the antigen, the substance responsible for inducing encephalomyelitis. Whole brain tissue is composed of a large number of substances, and it is probable that only one of these is actually involved. The antigen is fairly widely distributed, as evidenced by the fact that encephalomyelitis can be produced in monkeys by emulsions with adjuvants of brain even from such an animal as the chicken. Frog and fish brain, however, do not contain it. Thus far the antigen has been shown to be fairly resistant to heat or treatment with high-frequency sound waves. But it is destroyed by extraction of the brain tissue with alcohol or with acetone; neither the extracts nor the extracted residues induce the disease when administered with adjuvants.

Although the antigen has not yet been obtained in pure form, there is some evidence suggesting that myelin itself may be involved. Emulsions with adjuvants of fetal rabbit brain, which contains no myelin, did not produce the disease. To establish how soon after birth the antigen appeared in brain, the following experiment was carried out: Emulsions with adjuvants of the cerebrum and spinal cords of rabbits varying in age from one day to three months were prepared and injected into monkeys It was found that the spinal cords of rabbits three days old or older could produce encephalomyelitis, while the cerebrum did not show any capacity to induce the disease unless obtained from rabbits 12 days of age or over. This finding indicates a striking parallelism between the appearance of the antigen in the brain tissue and the development of myelin, since it is well established that myelination of the nerve fibers takes place during these periods and that myelin appears first in the spinal cord and last in the cerebrum.

But the evidence that myelin may be involved is only circumstantial. It does not constitute proof, and it is readily conceivable that another substance that makes its appearance simultaneously with myelin could be responsible. The final test will be the chemical isolation and characterization of the antigen in purified form, and it is toward this end that efforts are now being directed.

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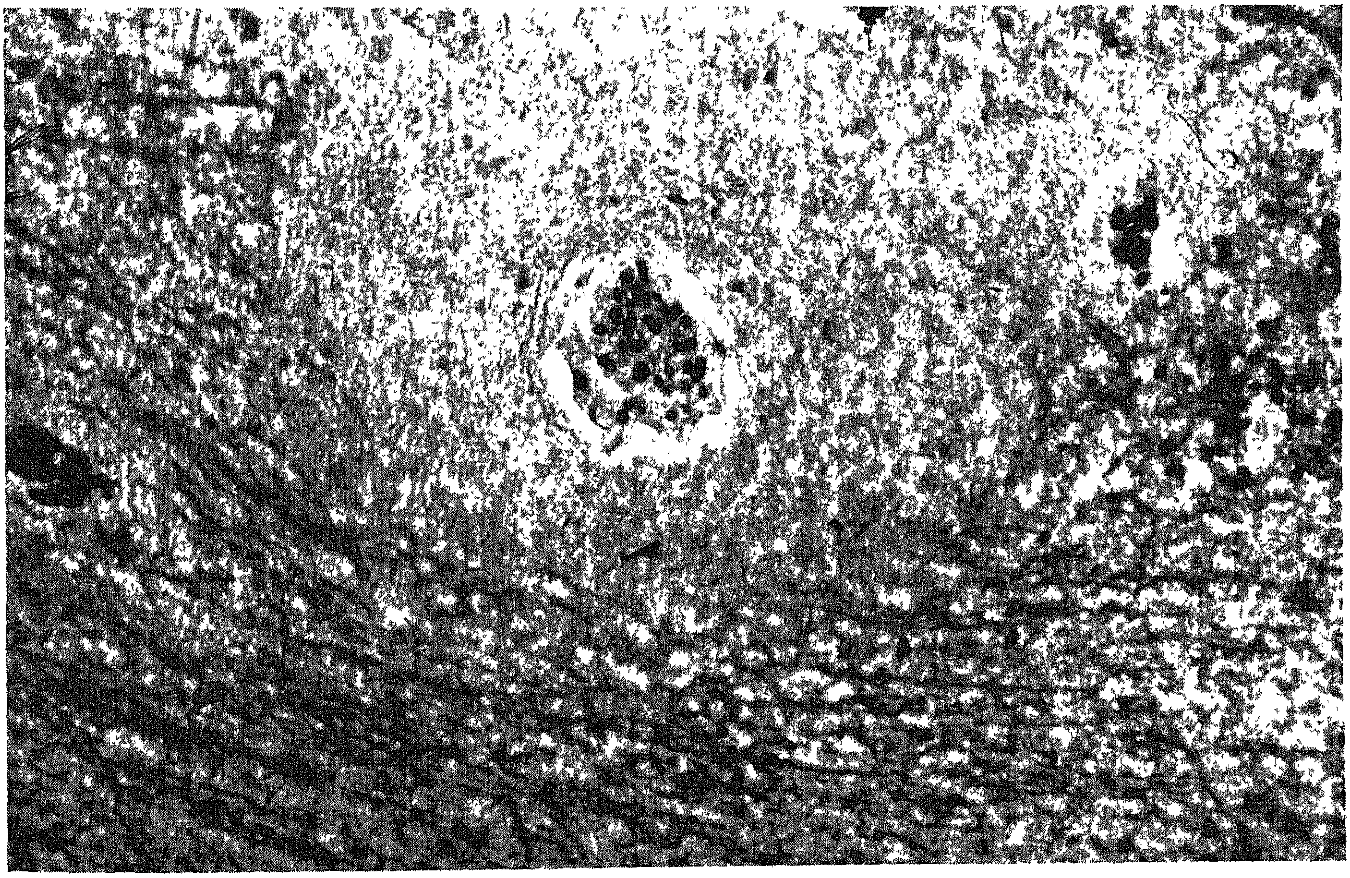
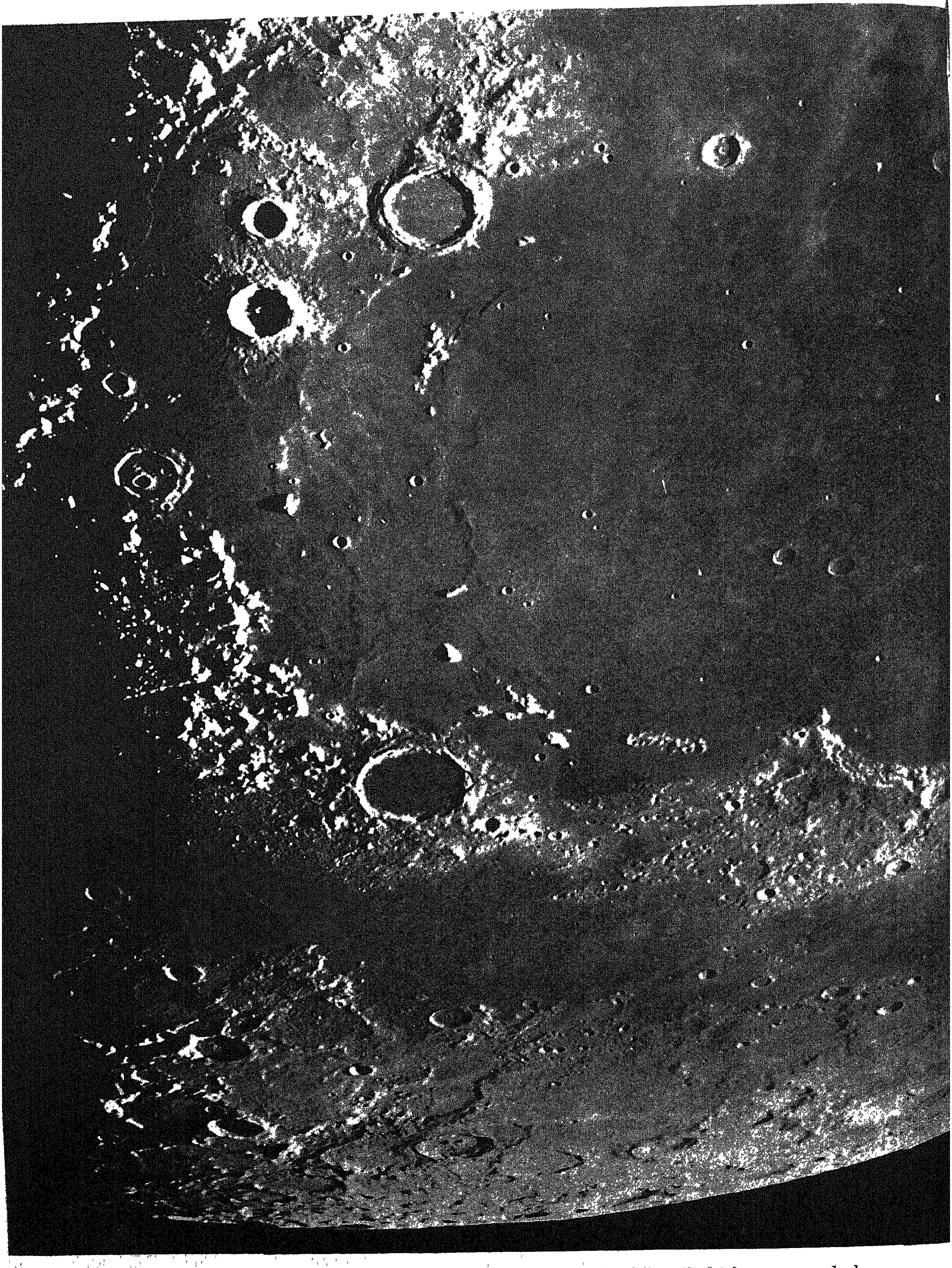
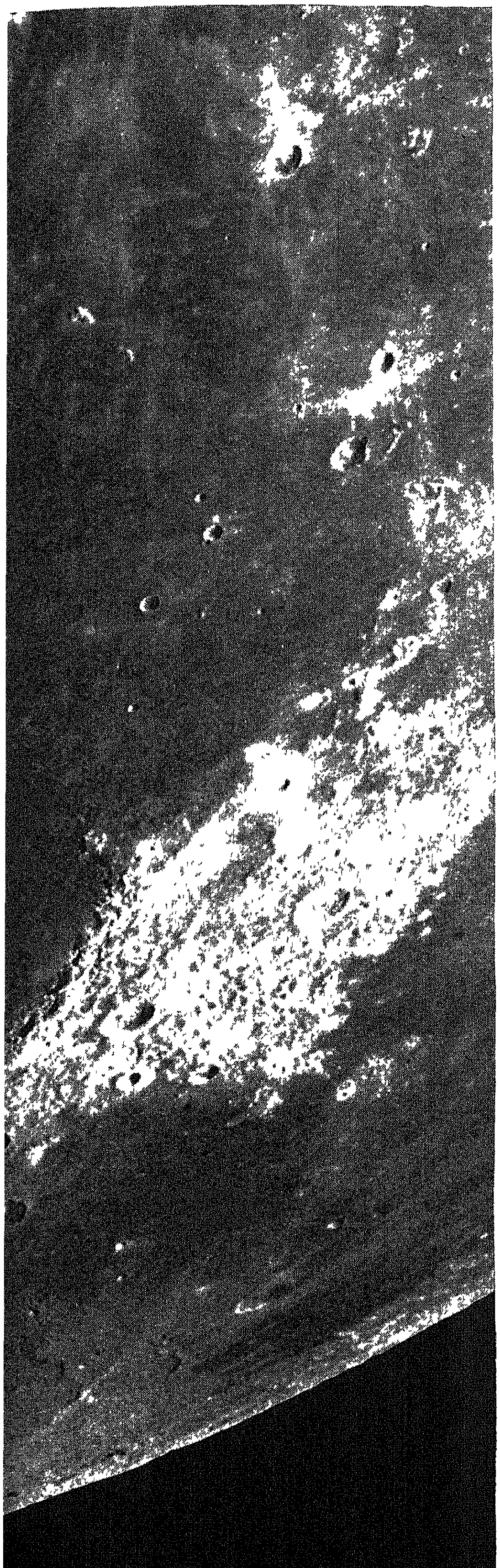
THE BRAIN of a monkey which was injected with the brain tissue of a rabbit is marked with hemorrhagic lesions in the white matter and the cortex. The most noticeable appear at the upper left in this photograph.



PHOTOMICROGRAPH of nerve tissue from the same monkey shows breakdown of tissue around a blood vessel (*center*). This demyelination is characteristic of acute disseminated encephalomyelitis in animals and man.



THE MOON'S SURFACE is pitted with large and small craters. Shown here is the region of Mare Imbrium, one of the relatively level "seas" which appear as dark areas to the naked eye. As noted in this article, the smaller



craters are deeper in proportion to their diameter than the large ones.

THE CRATERS OF THE MOON

The classical debate over their origin is gradually being resolved. The author sets forth his summary of the meteorite theory

by Ralph B. Baldwin

WHEN GALILEO first focused his "optik tube" on the moon in 1610, he set off a chain reaction of scientific controversy whose repercussions have continued to the present day. Tiny and imperfect as his telescope was, it gave earth-dwellers their first view of the weird, beautiful and endlessly puzzling formations on the moon's surface. These great ridges and hollows resembled the well-known mountain ranges and craters of the earth—and yet they were somehow different.

The peculiar feature of the moon's physiognomy was its huge cuplike depressions, named "craters" from the Greek word for cup. The closest counterparts to them on the earth appeared to be the craters of volcanoes. It was logically assumed, therefore, that the lunar craters also were made by volcanoes. True, they were much larger than any volcanic pit on earth. The biggest explosive volcanic crater is two miles in diameter, whereas the lunar craters range up to 146 miles. But no other sensible explanation seemed possible, and for 300 years the volcanic theory prevailed over all rival proposals, including such improbable ones as that the lunar craters are ice formations, coral rings, or the collapsed remains of great bubbles of molten matter.

As time passed, however, many scientists came to realize that the craters of the moon showed certain fundamental characteristics which demonstrated that they were not of exactly the same type as the earthly fire mountains. It was discovered, for one thing, that their apparent shape is a queer optical illusion. they look like deep cups, but actually in proportion to their width they are extremely shallow, more like saucers than cups. Furthermore, the floors of these craters are sunk below the surface of the surrounding plains Such a crater presents the greatest possible contrast to a terrestrial volcano Here is no volcanic neck, funneling molten materials from basement reservoirs to the surface, where they pile up as a tall, graceful mountain with a relatively tiny crater high in the peak. It is a new type of object, a structure scarcely known on earth. If it is volcanic in nature, it must be vulcanism of a kind completely unknown to modern geology.

So a fresh start had to be made, and it began with the measurement and more precise observation of the sizes and shapes of the lunar craters Were they all created by the same general process or by various random, local forces? This question could only be answered by attempting to find out whether there were any consistent similarities and mathematical relationships in the dimensions of the craters.

Toward the end of the 18th century the German astronomer J. H. Schröter made thousands of measurements of the moon's craters. He determined their diameters, their depths, the slopes of their inner and outer walls and the height above the surrounding moonscape of the rim material piled up around the craters' edges. Eventually his industry was rewarded by the discovery of a general relationship, still known as Schröter's Rule: "For each crater, the part of the material above the surface is approximately equal to the volume of the interior depression below the surface." Schröter's Rule has been confirmed in more recent times by the English astronomer T L. MacDonald and the German H. Ebert. The great majority of the lunar craters rigorously obey the rule, and the exceptions can be explained by deformations that took place after the craters were formed.

Schröter's finding pointed to an entirely new explanation of the craters' origin. They gave every appearance of having been created by shallow explosions of some kind that had blasted pits in the surface of the moon and piled up the shattered rock around the edges.

Ebert, MacDonald, the German J. F. J. Schmidt and the Englishman E. Neison went on to develop some other interesting facts. Ebert showed that the shapes of the craters fall into definite, con-

sistent patterns when their depths are compared with their widths. The smaller pits, up to about 20 miles in diameter, on the average are about 10 per cent as deep as they are broad. The larger craters tend to become shallower in proportion to their diameter. Thus the depth of a crater 60 miles broad is only about 5 per cent of its diameter, and for the largest craters, 100 miles or more wide, the depth is about 2.5 to 3 per cent of the width

There was another significant finding about the form of the craters: the outer slopes of their rims toward the surrounding plains are very gradual, ranging from one to eight degrees in the various craters. These consistently low gradients not only add to the evidence that the craters all belong to one family but rule out the possibility that they might have been formed by volcanic action. Material ejected by a volcanic eruption comes to rest on a relatively steep slope. On the earth this "angle of repose," at which the material stops sliding down a slope, is 30 to 35 degrees for fine volcanic ash and 40 to 45 degrees for coarser masses of slag and lava cinders. On the moon, with its relatively low surface gravity, the angle of repose would be even steeper. But the slope of the crater rims on the moon is nowhere near this order of magnitude.

Now what type of natural excavation on the earth answers the description of the lunar craters? There is one, and only one. It is the type of crater formed by the impact of a meteorite. There are several hundred known meteoritic craters on the earth. The largest is the great Arizona crater, 4,150 feet in diameter and originally at least 700 feet deep. A meteoritic crater 2,800 feet in diameter was recently reported in Australia, and others are available for study in Texas, Kansas, Arabia, Siberia and Argentina and on the Baltic island of Oesel.

It is certain that these pits were formed by the explosion of relatively small meteorites striking the earth at very high speed. The impact is so great that a meteorite blasts a hole of the order of 60,000 times its own volume in the earth's crust.

In fact, the meteoritic craters on the earth have exactly the same form as the larger ones on the moon in every respect but one. they are somewhat deeper relative to their diameters. But this is adequately explained by the relationship noticed on the moon, namely, the smaller a crater's diameter, the greater its relative depth.

So the most plausible explanation of the craters of the moon appears to be that they were created by the cataclysmic impacts of great meteorites. This theory, first suggested about 80 years ago, is now favored by the majority of investigators of the problem. But to suggest such a hypothesis is one thing, and to prove it is quite another Before any definite conclusions about the origin of the lunar craters can be drawn, it is necessary to relate what we know about them more precisely to phenomena known on the earth

To this end, the author has thoroughly combed the literature concerning all forms of terrestrial craters, pits and sinks. One of the most helpful sources of information is the great amount of knowledge accumulated during the recent war about craters blasted in the ground by bombs and by mortar and artillery shells. When all these data were compared, it became clear that the only type of crater that corresponds to the ones on the moon is the simple explosion pit formed by a single application of explosive power. Such a pit always has the same general form, whether it is produced by a bomb, a shell, a military mine or a meteorite.

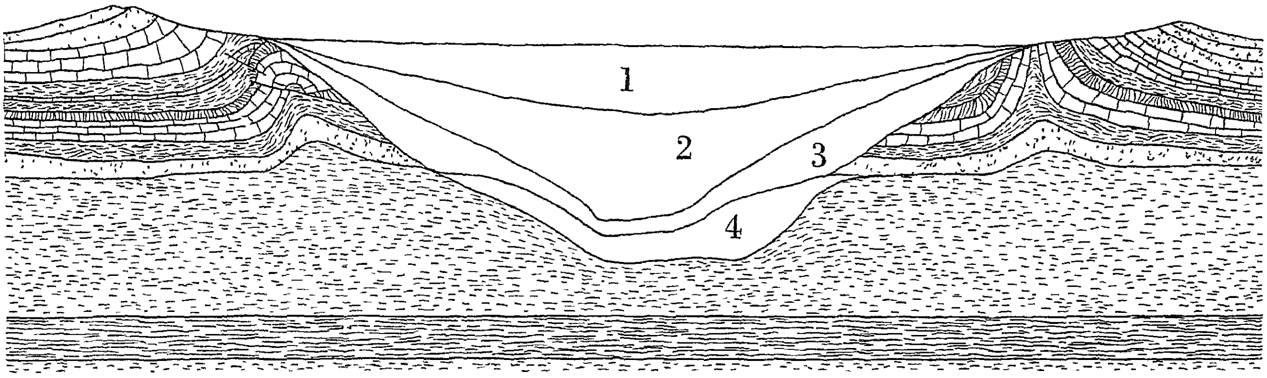
First, let us consider the simplest and most revealing relationship—the ratio of depth to diameter. There are 329 craters on the moon whose dimensions are known with sufficient precision for comparison. Many of them, however, overlap one another and are therefore distorted. For this study 193 lunar craters that are free of such distortions were selected. They range from one to 85 miles in diameter. Their depth-diameter ratios were then compared with those of many hundreds of explosion pits on the earth. The smallest were tiny craters less than three feet across and less than one foot deep, made by mortar shells. From these the crater sizes were arranged according to increasing diameter, up through those produced by larger shells, blockbuster bombs and great industrial detonations. The largest man-made crater was that formed by the explosion of a chemical plant which wiped out the town of Oppau, Bavaria, on September 21, 1921 This excavation, 400 feet in diameter and 90 feet deep, is only one thirteenth as large as the smallest measured lunar crater. But the gap is bridged by nature, which obligingly has furnished a number of meteoritic craters of varying sizes that overlap the largest man-made pits and approach the dimensions of the smallest we can see on the moon. The four meteoritic craters chosen for comparison ranged from a 30-foot pit in Australia to the 4,150-foot hole in Arizona The original dimensions are not adequately known for the other meteorite craters.

When the depth-diameter ratios of all these craters are plotted graphically, using a logarithmic scale because of the very wide spread in their dimensions, the result is striking. The chart at the top of page 24 shows that these ratios, from the smallest man-made to the largest lunar craters, make a beautifully smooth curve, which obeys Ebert's rule that as the diameter of a lunar crater increases its relative depth decreases. The bomb, meteorite and moon craters form a family relationship which is too startling, too positive, to be fortuitous The only reasonable interpretation of the curve is that the lunar craters, like the terrestrial, sprang from the same known cause. All of them form a continuous sequence of explosion pits, each dug by one blast.

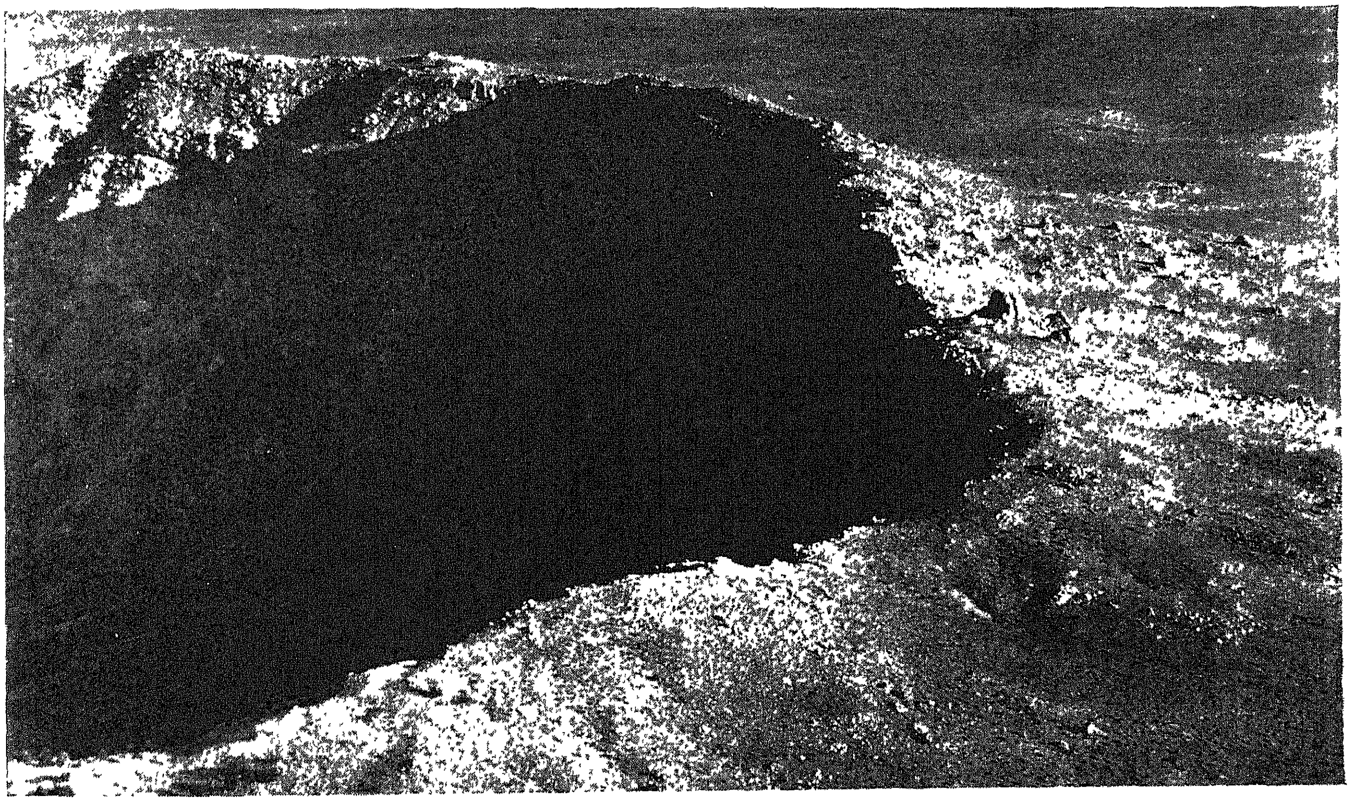
There are other correlations that further confirm the hypothesis. A crater formed by the blast of a bomb, a shell or a meteorite invariably is circular or nearly circular. This is true regardless of the angle at which the projectile hits, almost to the limiting case where it ricochets along the ground before it explodes The blasted earth forms a low rim around the pit, steep on the inner face and dipping gradually to the plain on the outer side. The larger the crater, of course, the greater the height of its rim. And this description exactly fits the craters on the moon. Here again comparison of the relation between the diameters and rim heights of craters produces a smooth curve for terrestrial and lunar craters alike, as shown in the chart at the bottom of page 24.

Studies of the explosion pits on the earth yield a neat method of checking Schröter's observation that the material in the rims around the lunar craters would just fill the craters if it were replaced. The plotting of the ratios between diameter and depth and between diameter and rim height of the various craters produces two equations that give the ratios for a crater of any size. The first of these equations provides a method for computing the total depth of a crater, given its diameter. The second makes it possible to calculate the height of the rim. Subtracting the rim height from the total depth gives the depth of the crater below the surrounding ground level. From this information, plus certain other general data including the width of a crater's rim (which averages roughly one fourth of its diameter), it is possible to calculate the volume of material displaced from the crater. On the basis of this volume, a theoretical value can be calculated for the height of the rim of a crater of any given size. To check Schroter's Rule, this theoretical height was compared with the actual measured heights of lunar crater rims. The agreement between the theoretical and observed heights was excellent.

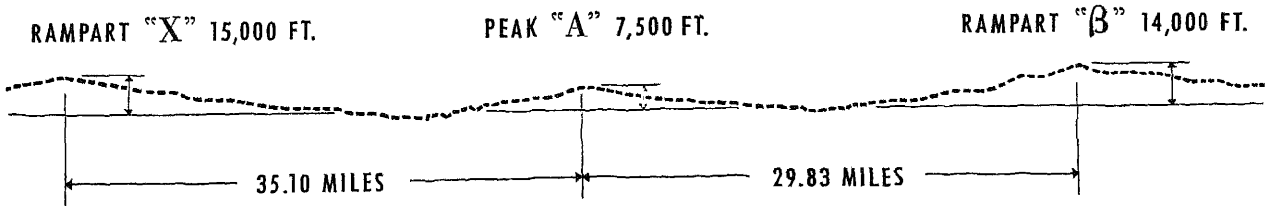
The foregoing analysis proves only that the moon's craters were formed by great explosions; it does not show the source of the energy that produced such explosions. But it can be said that only one known source of energy is vast enough to yield the observed results—the energy carried by great meteorites. When a meteorite strikes a rocky crust and is stopped quickly a little below the surface, the kinetic energy of its motion is transformed into heat. The heat is so



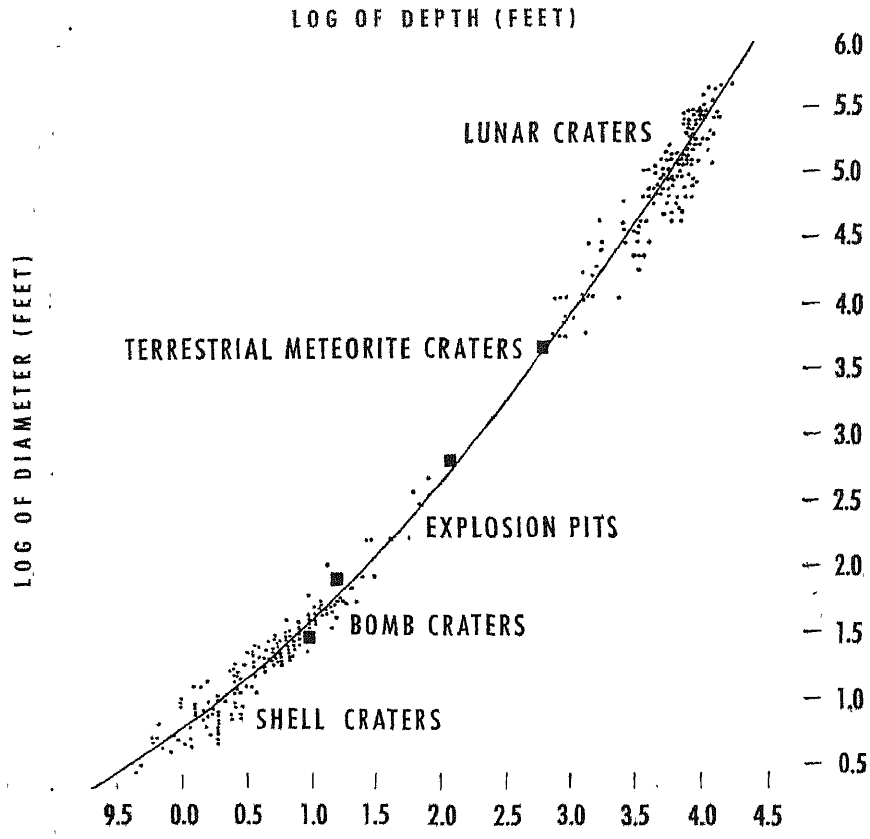
TERRESTRIAL meteor crater near Odessa, Tex., has profile rather similar to lunar craters. Odessa crater is filled with silt and sand (1); older silt, sand, caliche and pebbles (2); fragments of rock (3); and rock dust (4).



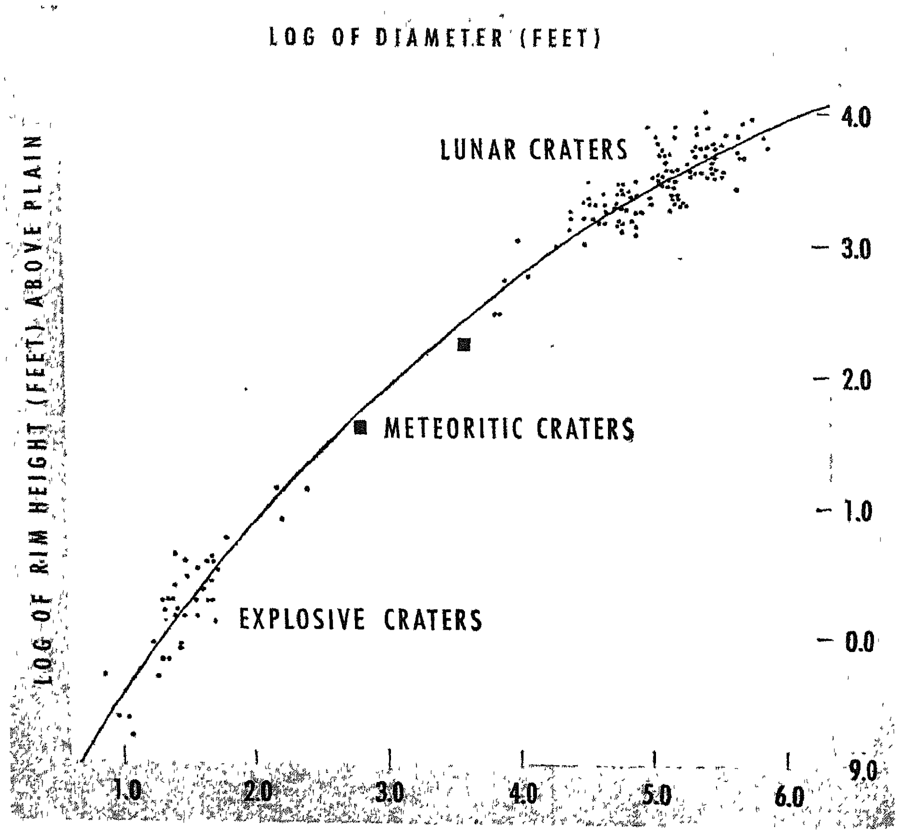
METEOR CRATER in Arizona, like the Odessa crater, appears much deeper than the craters visible on the moon. Terrestrial craters are much smaller than lunar, but they still adhere to the diameter-depth rule.



LUNAR CRATER Theophilus appears practically flat in comparison with terrestrial craters. Its rim, however, towers 15,000 feet. Profile was measured at the McMath-Hulbert Observatory of the University of Michigan.



DIAMETER AND DEPTH relationships of craters on the earth and the moon follow the same curve. Logarithmic scale is used because of great difference in size between craters measured on earth and visible on the moon.



DIAMETER AND RIM HEIGHT relationships of terrestrial and lunar craters also follow the same rule. Another similarity between terrestrial explosion craters and lunar craters is that they are almost perfectly circular.

great that it vaporizes the rocks at that spot, and these gases blast the crater.

How big were the meteorites that gouged the craters in the moon? C. C. Wylie of the University of Iowa calculated that the great crater in Arizona was produced by a nickel-iron meteorite between 30 and 64 feet in diameter. If the meteorite were spherical and, say, 50 feet in diameter, it dug a hole about 60,000 times its own size. If we assume that this ratio would hold generally, lunar craters of the order of 20 miles in diameter were produced by meteorites about 750 feet in diameter, and 80-mile craters by meteorites of 2,700 feet.

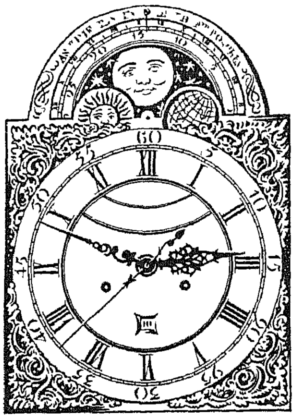
ANOTHER method is to consider the energy needed to blast terrestrial craters of any given size, and then extrapolating to larger pits. By assuming that meteorites of nickel and iron struck the moon with a velocity of 10 miles per second, we can calculate how large they must have been to carry the required amounts of energy. This method yields slightly larger values for the meteorite sizes than the first one. Even so, the meteorites that produced the great lunar craters are surprisingly small. The biggest crater on the moon, 146-mile Clavius, probably was blasted by a cosmic fragment no more than one or two miles in diameter.

The face of the moon is scarred by at least a million craters visible from the earth and probably by billions of tiny pits that we cannot see. If they were made by meteorites, why do we not find many on the earth? The moon has always been a companion of the earth, and the history of the one must be but a paraphrase of the other's. At the beginning billions of meteorites must have fallen on the earth as well as on the moon. The difference, however, is that on the earth the forces of erosion would erase meteoritic craters within a relatively short time. On the moistureless, atmosphereless moon there has been no erosion for billions of years.

Thus the moon bears on its surface an imperishable record, frozen in rock, of its history since its crust was formed. In its early ages the moon probably evolved from a gaseous to a liquid state. It certainly solidified under an explosive rain of meteoritic fragments. After it hardened its meteoritic craters remained as permanent scars. The rain of meteorites abated as most of them were swept up, and at present such collisions are few and far between. The moon's face is still changing, but its encounters with meteorites of any significant size are so rare that in man's brief history little visible variation has appeared.

Ralph B. Baldwin is author of the recent book The Face of the Moon.

SCIENCE AND THE



Tempest in a Hearing Room

SINCE early May, the Atomic Energy Commission, which had received comparatively little attention during its first two years, has held a prominent position on the Washington political stage. The charges against the Commission and Chairman David E. Lilienthal—prosecuted largely by Senator Bourke B. Hickenlooper of Iowa, former chairman of the Joint Congressional Committee on Atomic Energy and a candidate for re-election to the Senate next year—were pegged on certain recent incidents but were not basically new. The whole performance has been disquieting to the U.S. scientific community because it appears to reflect a continuing lack of understanding of the atomic energy enterprise in some quarters in Congress, and a continuing tendency toward political interference in science (*see page 30*).

Here is a day-by-day account of events up to the time this issue of SCIENTIFIC AMERICAN went to press.

May 10—Fulton Lewis, Jr., Mutual Broadcasting System commentator, complained in a news broadcast that the AEC had awarded a fellowship to a member of the Communist party, Hans Freistadt, a graduate student and part-time instructor in physics at the University of North Carolina.

May 12—Lewis' charge was repeated in Congress by Representative W. Sterling Cole, New York Republican, and Senator Clyde R. Hoey, North Carolina Democrat.

May 14—Hickenlooper asserted that an AEC fellowship had also been awarded to a "Communist" postdoctoral fellow at an Eastern university

May 16—Lilienthal told the Joint Congressional Committee on Atomic Energy that the National Research Council, which administers the fellowship program for the AEC, had recommended a fellowship for Freistadt. He explained that "the work carried on under the fellowship program is overwhelmingly concerned with non-secret areas of research"; Freistadt was to do non-secret work in relativity. On the advice of the Council, the Commission had decided not to require security clearance of candidates for such fellowships. Lilienthal warned that to require loyalty clearance for workers in non-secret fields would create a precedent "of grave and far-reaching consequence to our scientific and educational system." His views were seconded by A. N. Richards, president of the National Academy of Sciences, parent body of the National Research Council.

May 17—In a story by William Bradford Huie and Jerry Greene, the New York *Daily News* reported that three quarters of a pound of uranium 235 had disappeared from the Argonne National Laboratory "Key counter-intelligence officers who have been sweating blood in a frantic race to find the missing bomb component," the *News* announced, "now believe they have failed and that the uranium is in Russian hands. The loss—or more probable theft—is considered the greatest threat to national security ever to be discovered in peacetime." The story quickly appeared on front pages across the country, but the facts turned out to be not quite as first reported. The AEC conceded that some uranium had been missed in the Argonne Laboratory's February inventory. The missing material, however, was an enriched uranium compound that contained only 32 grams (1.05 ounces) of U-235. Of this, 25 grams had already been recovered from laboratory waste.

May 18—Senator Brien D. McMahon, chairman of the Joint Committee, announced that an additional three grams of the missing U-235 had been recovered. He said he was satisfied that no material had been stolen, and the FBI had declared itself convinced no espionage was involved in the incident.

May 19—McMahon announced that his committee would inquire into the disappearance of the U-235 and the award of fellowships to Communists. Committee members were angry, he explained, over a six-week delay by the AEC in reporting the loss of the U-235 to the FBI. The Senate Appropriations Committee subcommittee dealing with AEC funds, headed by Senator Joseph C. O'Mahoney, Wyoming Democrat, entered the fray with a second inquiry into the fellowship program.

May 20—Fulton Lewis, Jr., tossed in a new charge. that two bars of uranium metal, taken from the Hanford plutonium plant by security officers in a security test, had not been missed by supervisors of the plant for 90 days, after which they were returned by the security men. Meanwhile the alleged second Communist among the 500 AEC fellowship holders was identified as I. S. Edelman of Harvard Edelman was described by Shields Warren, director of the AEC division of biology and medicine, as a physician who had been denied clearance for secret work, but against whom the evidence was inconclusive. He had been given a fellowship to carry out critically important non-secret medical research for which he had "outstanding" qualifications. (Edelman later appeared before the Joint Committee and satisfied it that he was not a Communist.)

May 21—The AEC modified its stand and agreed to bar Communists from fellowships. To implement its decision, the Commission adopted the requirement that future candidates for fellowships must take a loyalty oath and file non-Communist affidavits. Concerning the removal of the uranium bars at Hanford, the Commission explained that this was one of a series of routine security checks and that it had resulted in the tightening of security procedures.

May 22—Hickenlooper, who had supported Lilienthal during the battle over his original appointment to the Commission two years ago, called on President Truman to oust the AEC chairman on grounds of "incredible mismanagement." The Iowa Senator asserted there was "perhaps even more serious evidence of maladministration" than was involved in the U-235 and fellowship incidents.

May 23—The Joint Committee decided to hire an outside consultant to investigate the loss of the U-235 at the Argonne Laboratory and the Laboratory's procedure for safeguarding valuable materials. O'Mahoney's appropriations subcommittee extended its investigation of the AEC from the fellowship program to the missing U-235, the Hanford uranium bars and the shipment of isotopes abroad. Lilienthal conceded before the O'Mahoney committee that the Commission had made a "substantial error" in failing to notify the FBI sooner of the disappearance of the U-235 sample. On the same day AEC Commissioner Lewis L. Strauss disclosed that he had dissented from the Commission's decision to make isotopes available to research workers in foreign countries. Lilienthal and Kenneth S. Pitzer, AEC director of research, replied that so far as scientists could determine there is little or no risk of their being useful for military purposes.

May 25—Lilienthal asked the Joint Committee for a full investigation of Hickenlooper's charges of "incredible mismanagement." Such an inquiry, he said, would show that the AEC's record "is a proud one." Senator Harry P. Cain, Republican of Washington, proposed repeal of the Atomic Energy Act and

CITIZEN

return of atomic energy to the National Military Establishment

May 26—President Truman gave Lilienthal and the AEC his unqualified support and termed the attack on them "pre-election campaign material." He said, "I personally know the country's position in atomic energy. We are making good progress . . I deplore the fact that relatively trivial items have been blown up to proportions that threaten the integrity of the program. The plain fact is that the atomic energy program is in good shape—and in good hands . . I have entire confidence in Mr. Lilienthal."

May 28—Hickenlooper stated that he was ready to "produce proof" of his charges against Lilienthal. Scientists from several universities and laboratories, coming to Lilienthal's defense said that the new fellowship rules forced on the AEC would add to the Commission's difficulties in carrying on its many activities. W. A. Higinbotham of the Brookhaven National Laboratory said that more than 100 qualified atomic scientists had already been excluded from the atomic energy program by clearance difficulties.

May 29—Angrily demanding a showdown in a newspaper interview, Lilienthal charged Hickenlooper with conducting a "smear" campaign against the AEC, and with making a "calculated" attempt to arouse fears of an "approaching collapse" of the atomic bomb program with "vague, un-American" accusations.

May 31—The Joint Committee agreed to let Hickenlooper develop his charges in face-to-face hearings with Lilienthal. The O'Mahoney subcommittee wrote into the AEC's 1949-50 appropriation bill a requirement for FBI investigation of all AEC fellowship applicants.

June 1—The Joint Committee's formal inquiry opened before a quorum of newsmen, radio commentators, newsreel photographers and television broadcasters. Hickenlooper made three charges against the AEC 1) excessive turnover of personnel, 2) too frequent use of its power to give security clearance to employees in emergency cases before full investigation by the FBI, 3) retention of two scientists on the AEC payroll by General Manager Carroll L. Wilson despite unfavorable reports by the Commission's security officer. Lilienthal replied that the AEC's personnel turnover rate (50 per cent in two years) was no higher than in other Government agencies, and considerably lower than in private industry. He explained the large number of emergency personnel clearances by pointing out that several of the plants were near a breakdown when

the Commission took them over from the Manhattan District, and workmen had to be employed quickly for repairs

June 2—The bottle that had held the missing U-235 was found in a dump for radioactive waste at the Argonne Laboratory. Hickenlooper charged that an Argonne guard with access to the safe in which the missing bottle had been stored had a police record, including a charge of grand larceny. AEC Manager Wilson replied that the guard had been employed by the Army before the AEC took over the project, when his record, which included no convictions, was discovered on a recheck by the Commission, he was transferred to work not involving secret materials.

June 6—Hickenlooper charged that the AEC had kept on its payroll a score of employees against whom the FBI had found "derogatory information." As his first case, he cited "Mr. A," in charge of preparing AEC reports to Congress, who had been suspended at one time because of an unfavorable FBI report. Lilienthal pointed out that all of the employees listed by Hickenlooper, including "Mr. A," had eventually been cleared by loyalty boards. At least 10 of the cases, he added, had occurred while Hickenlooper was chairman of the Joint Committee, and the Committee had concurred in the loyalty board findings. The AEC chairman demanded that "Mr. A," who he said had been clearly identified by Hickenlooper although he was not named, be given an opportunity to defend himself before the Committee. The Committee then held a series of closed sessions, extending over several days, to decide whether accused individuals should be discussed and heard at public hearings.

June 7—Secretary of Defense Louis A Johnson issued a statement expressing satisfaction with the operations of the AEC and disclaiming any desire by the National Military Establishment to resume control of atomic energy. "The military establishment has not attempted, and will not attempt," he said, "to take atomic energy away from civilian control and turn it over to the military. We have had no desire to handle the matter. We have none now. We want none of it in the future."

June 8—Hickenlooper charged that a shipment of radioactive iron to Norway for metallurgical research violated the Atomic Energy Act. He said that the shipment was to be used for developing alloys for jet engines and rockets. (Norwegian officials promptly denied this.) Hickenlooper also argued that shipment of radioisotopes was contrary to a section of the Act which forbids the transfer of information to foreign countries on the use of atomic energy for industrial purposes. Chairman McMahon, who had sponsored the Act, disputed this interpretation.

June 9—Commissioner Strauss, testifying before the Committee, explained his disagreement with the other commissioners over the shipment of isotopes He said he opposed the shipments because he thought isotopes might be useful to other nations for metallurgical research and "for the possible mutation of agents for use in biological warfare."

June 10—The Joint Committee decided, 9-to-8, to consider no more of Hickenlooper's loyalty cases in public Chairman McMahon explained in a letter to Hickenlooper: "You may conceivably take the position that the mere existence of derogatory information on a particular individual is sufficient to disqualify him for atomic energy employment. But the law . . . permits the Commission to exercise discretion, to weigh favorable against unfavorable data. . The individual involved in Case A has already been sufficiently identified to cause him genuine embarrassment. If discussion of other cases had the same result . . . the effect on the morale of atomic energy employees might become serious . . ."

June 13—J. Robert Oppenheimer, chairman of the AEC General Advisory Committee, an agency created by the Atomic Energy Act to watch the project and report directly to the President, testified before the Joint Committee that his group fully endorsed the "competence and devotion to duty of the Commission." The Advisory Committee said: "Better weapons have been developed and tested, the production of materials has been substantially increased and assured, and a sound and forward-looking program has been established." Oppenheimer ridiculed the suggestion that the export of isotopes endangered the security of the U.S. He added that the Advisory Committee believed that in its security precautions the Commission had been too conservative. Said Oppenheimer: "I think the Commission can go further toward making information public which is now secret."

June 15—Hickenlooper presented as evidence of "mismanagement" the fact that a new plant at Hanford for processing plutonium, originally estimated to cost $6,255,000, eventually cost $25,219,000. Lilienthal, conceding that the costs had not been closely supervised by the AEC, said that the increase was due to revisions of plans and the great rush in which the plant was built. It was considered urgently needed to supply material for new types of bombs tested at Eniwetok last year The plant, said Lilienthal, places the refining and fabrication of plutonium metal on a factory production basis, instead of the "breadboard" operation previously carried on at Los Alamos.

Arthritis Remedies

CORTISONE and ACTH, two widely hailed new remedies for rheumatoid

arthritis, have excited great interest at recent medical meetings. Cortisone also looks promising as a treatment for rheumatic fever, and ACTH as a treatment for epilepsy. Both are difficult to manufacture, however, and even if successful may not be available for general use for several years.

Cortisone (originally named "compound E") is an adrenal cortical hormone, prepared from cattle bile by a difficult partial synthesis involving 37 steps. ACTH (adrenocorticotrophic hormone) is a pituitary secretion which stimulates the adrenal cortex. It is obtained from dried hog pituitary gland by means of a low-yielding extraction process.

In a test at the Mayo Clinic early this year, cortisone brought dramatic relief to 16 patients with rheumatoid arthritis. Individuals who had entered the Clinic in wheel chairs were able to run within a few days. A Mayo clinic film showing their recovery caused much excitement at the recent International Congress on Rheumatic Diseases in New York. Three rheumatic-fever patients also "responded well" to cortisone treatment. Similar results in arthritis were obtained with ACTH in Boston at the Harvard Medical School, Peter Bent Brigham Hospital, Robert Breck Brigham Hospital and the House of the Good Samaritan. The Boston investigators also found that ACTH restores normal brain-wave patterns in a way that suggests the hormone may be of value in epilepsy, which is marked by extreme disturbance of brain-wave patterns.

Cortisone appears to be the primary curative agent, while ACTH acts by stimulating secretion of the adrenal cortical hormone. In both cases relief lasts only as long as the drug is used.

Research leading to the trial of cortisone in arthritic disease was begun by Philip S. Hench of the Mayo Clinic more than two decades ago. He had observed that patients experienced remissions of rheumatoid arthritis during pregnancy, attacks of jaundice and immediately after surgical operations. He felt that this might be due to increased activity of the adrenal cortical gland, which is involved in responses to stress (*see page 44*). Adrenal cortical stimulation may likewise be responsible for the temporary relief sometimes afforded to arthritis patients by injections of bee venom. Last year Merck and Company chemists succeeded in producing a small amount of cortisone for trial. ACTH came from the Armour Research Laboratories.

Meetings in August

AMERICAN Institute of Electrical Engineers. Pacific general meeting. San Francisco. August 23-26.

American Mathematical Society. Boulder, Col. August 30-September 2.

FIVE COMMISSIONERS run an $800 million industry. They are Chairman David E. Lilienthal *(upper left)*, Sumner T. Pike *(upper right)*, Henry D. Smyth *(center)*, Lewis L. Strauss *(lower left)* and Gordon Dean.

THE ATOMIC ENERGY COMMISSION

Under the baleful shadow of bomb politics, it is making halting progress toward the goal of constructive uses for atomic energy. A report on the vast AEC enterprise

by Leon Svirsky

DID the explosion at Alamogordo on July 16, 1945, mark the beginning of an era—or the end of one? Four years of the "atomic age" have not diminished but enhanced the importance of this question. Bound up in it are practical problems and issues of policy on which hang the strategy and the future of science in the U.S.

On the fourth anniversary of the first atomic bomb, it is clearer than ever that, whatever the bomb's effects upon warfare and politics, in science it was the almost irrelevant culmination of a chapter that began with Henri Becquerel's discovery of radioactivity in 1896 and ended with the discovery of uranium fission in 1939. The making of the bomb itself was an exciting denouement, but most of those who took part in it have now returned to the basic study of the still mysterious atomic nucleus—an inquiry in which the fission of uranium no longer holds much promise of enlightenment, nor indeed much interest, for physicists. The mushroom splendor of the "atomic age" has obscured, and continues to obscure, the meagerness of man's understanding of the forces of nature, and the conditions for further progress. Scientists are well aware, if the public is not, of the need for a return to fundamental work In basic science the period of reorientation and retooling that followed the bomb is now about over, and a new chapter has begun. Yet in a political sense the bomb still dominates U.S. science, posing for scientists and laymen alike some serious questions as to how and to what ends research shall be supported.

These are inescapable impressions that an outside observer brings away from a study and tour of the vast enterprise conducted by the Atomic Energy Commission, the somewhat anomalous offspring of the atomic bomb. The AEC project is surely one of the most impressive performances ever staged by man Chairman David E. Lilienthal has called it "the largest, most complex and most extensive scientific, educational, industrial, technical and weaponeering undertaking in the history of the world"—which is a considerable mouthful but hard to deny. The AEC's $800 million budget for the coming year places it in the top rank of America's giant industries. It owns some $3 billion worth of plant and real estate; maintains 1,270 factories, laboratories, offices and other installations reaching into nearly every state, has hundreds of industrial contractors and suppliers; has educational arrangements with 58 universities and research contracts with dozen of others, is supporting the major part of the basic work in physics in the U.S.; and at its three national laboratories—Oak Ridge, Argonne and Brookhaven—is building the most richly equipped physical and biological research centers on earth.

Yet the Atomic Energy Commission remains essentially an agency for making bombs, and its scientific facilities and expenditures are but parasitic appendages to that central purpose. At least 90 per cent of its huge budget has been devoted directly or indirectly to the development and production of fissionable materials and weapons. And because its business is the world's most zealously guarded secret, much of its far-flung support of scientific work is subject to such controls and restrictions as science has never before known.

No one is more unhappily aware of the difficulties and dangers of this situation than Lilienthal and his fellow commissioners. Presiding over an enterprise which most citizens consider it unpatriotic even to inquire about, and in which the loss of seven grams of uranium 235 becomes front-page news and the subject of a Congressional investigation, the AEC occupies a position beset with frustrations. In its relations with Congressmen, many of whom have adopted the working principle that the less heard from or about the Atomic Energy Commission the better, the Commission has generally followed a policy of extreme caution—some think excessive caution. But in a quiet way Lilienthal and his colleagues have been seeking to reduce the isolation of their immense enterprise from the main currents of American life—an isolation which has been a substantial handicap to the AEC, to science, to technology, to industry and to the hopes for the use of atomic energy for peaceful purposes

The Reactor Program

Nothing illustrates the Commission's difficulties more cogently than the snail's pace of its progress, in the two and a half years since it took over from the Manhattan District, toward the development of uranium as a fuel for useful power. This part of its task, known as the "reactor" program, has been virtually at a standstill. Partly this is due to the Commission's unavoidable preoccupation during its first two years with the job of shoring up the production of fissionable materials by the repair and expansion of the deteriorating, war-built plants; partly it is

due to the formidable nature of the reactor problem itself, partly to disagreements within the AEC as to the best way to begin, partly to rivalry between the Air Force and the Navy for priority on its first nuclear power plant—but fundamentally the delay has been due to the lack of public information or any real public pressure for the power program. The Commission's indecisions have now been resolved, and Lilienthal believes that "we have begun to get traction and from here on can expect a good deal more movement" in the experimental phases of the reactor project. But it has become clear that the development of an economically practical nuclear power plant will be accomplished, if it can be accomplished at all, only by an expenditure of brains and money at least as great as that required for the original development of the atomic bomb.

What is so difficult about it? If the energy in the uranium nucleus can be harnessed in a bomb or in a chain-reacting pile—"a bomb in slow motion," as Lilienthal describes it—why should there be any great problem about applying this power to run an engine? The answer requires a review of some of the fundamentals of the uranium chain reaction, and serves as a good starting point for a description of the AEC's tremendous operation.

Fission

The entire atomic energy enterprise rests ultimately on one basic reaction—the splitting of uranium 235, one of the lighter isotopes of the heavy element uranium, as the result of its capture of a neutron. Actually it is not U-235 itself that splits but an extremely short-lived daughter, U-236, formed when the neutron is added to the parent. U-236 is so unstable that it cracks almost instantly, within millionths of a second, into two nearly equal parts, recognizable as lighter elements in the middle of the periodic table. These product elements are not always the same; some 40 to 45 different species of atoms have been identified as fission products. The combined weight of the two atoms into which the uranium atom splits is less than that of the parent; the lost mass of the annihilated matter is converted into energy, mainly in the form of gamma rays and the kinetic energy of the flying fragments. And the fission products themselves are highly unstable, *i.e.*, radioactive, giving off particles and energy until they decay into stable forms. The energy released by the fission of a single uranium atom is 200 million electron volts. For the purposes of a chain reaction, however, the most important product of the fission process is the release of free neutrons for the production of further fissions.

Uranium fission is not a man-made phenomenon, it can occur in nature. U-235, though a rare species, is present in all natural uranium in the proportion of one part to 139 parts of the common isotope U-238. Occasionally a U-235 atom in uranium-bearing rocks may capture a stray neutron. It fissions, releasing energy and new neutrons. But the probability that these neutrons will be captured by other U-235 atoms and produce further fissions is so small as to be practically nonexistent. And the reasons for this are at the heart of all the problems and difficulties in developing a practical power reactor.

Capture of Neutrons

The first reason is that neutrons are exceedingly eligible for capture by nearly all kinds of matter. Most elements, especially the heavier ones, have a strong affinity for neutrons and greedily absorb them. In the rocks any neutrons produced by an accidental fission have an almost infinitely greater chance of being absorbed by the abundant other materials present than by another rare U-235 atom. Consequently the first step in building a chain-reacting pile, or reactor, is to refine natural uranium, removing all the impurities that would absorb neutrons profitlessly. A chain reaction can be maintained in a pile of uranium oxide, because oxygen is a poor absorber of neutrons, but in that case also the compound must be exceedingly pure.

The second problem is that, in uranium itself, fissionable U-235 is at a double disadvantage in its competition for neutrons with U-238. Not only are the U-238 atoms much more abundant but they intercept neutrons at a more likely speed. When neutrons are released by a fission, they are traveling at very high velocity. At this high speed no type of atom has a high probability of capturing them. U-238 absorbs neutrons of intermediate speeds; there is a certain resonance velocity at which it gobbles them up. U-235, on the other hand, is partial to slow neutrons; it captures them most readily when they move at so-called thermal velocities, that is, the normal rate of vibration of the atoms in a solid. Obviously the neutrons are likely to be absorbed by U-238 at intermediate speeds before they can slow down to the thermal speed favored by the rare fissionable atoms. One way to get around the difficulty, of course, is to get rid of the U-238 and use almost pure U-235, as in the bomb. U-235 *can* capture fast neutrons (though with a lower probability), and if there is little U-238 present to take them out of circulation, the chain reaction can proceed. But the separation of U-235 is costly; practical economics demands that a reactor operate, if possible, on natural uranium. A chain reaction can be established in natural uranium by slowing down the fast neutrons quickly so that as many as possible will arrive at the thermal speed favored by U-235 before they can be absorbed by U-238. This is the function of the moderator in a reactor. Its job is to brake the neutrons from millions of electron volts (the physicist's measure of neutron speed) to less than three hundredths of an electron volt within a foot or two.

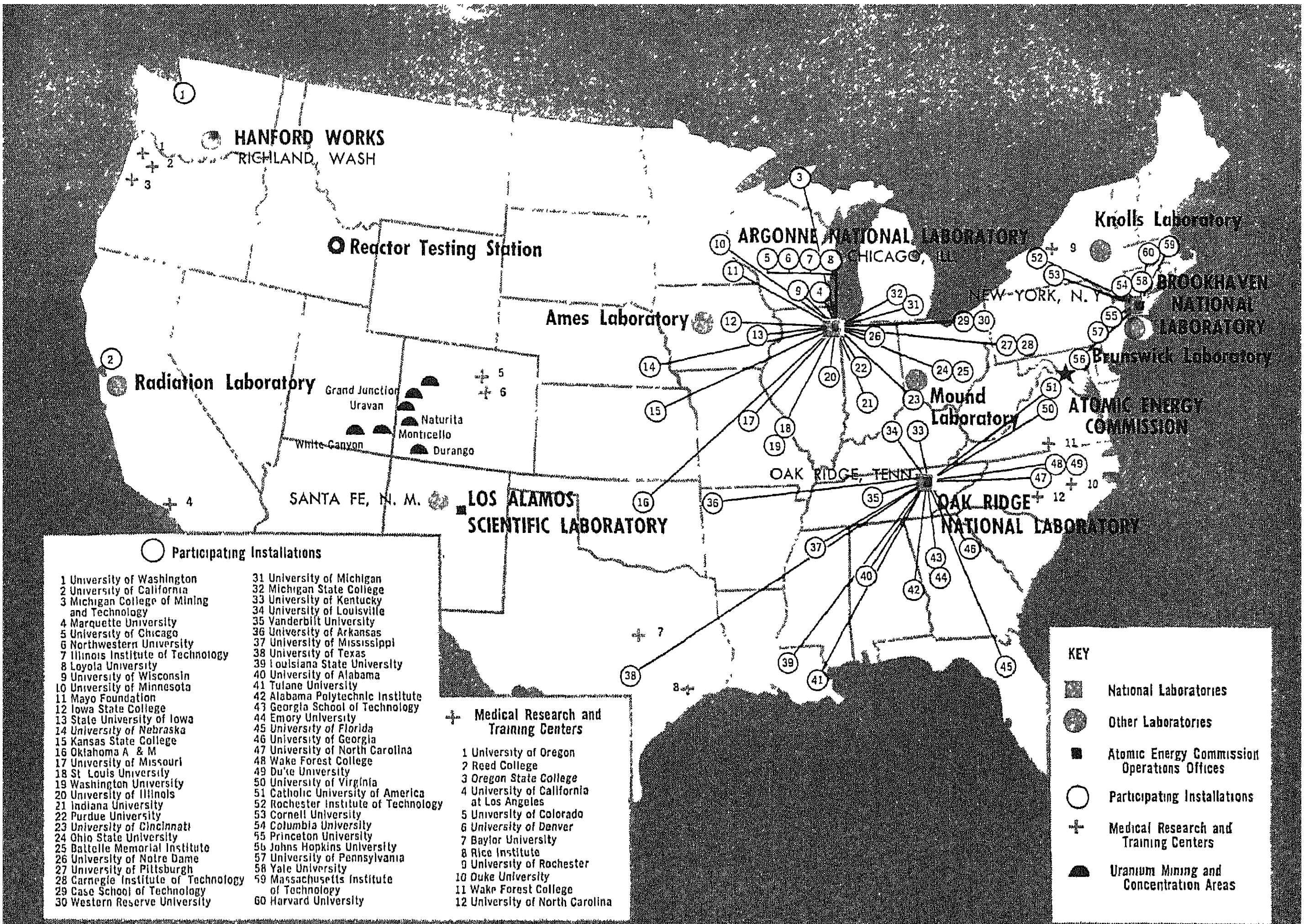
The material used as moderator (1) must not absorb neutrons and (2) must be light in mass. The neutrons are slowed by a series of collisions with the nuclei of the atoms in the moderator. The reason why these atoms must be light can be illustrated by comparing the particles to billiard balls. A billiard ball that hits a much more massive object than itself (*e.g.*, a large iron ball) rebounds with little loss of speed, it is slowed most when it collides with a body of about its own size, such as another billiard ball. In a reactor the nuclei of light atoms are effective in slowing neutrons because they are comparatively close to the weight of a neutron, which has about the mass of a hydrogen atom.

The materials that come closest to fulfilling the specifications for an ideal moderator are pure carbon (graphite), the light metal beryllium, and heavy water—ordinary water will not do because common hydrogen is an avid neutron-absorber, whereas the heavy hydrogen isotope (H^2) in heavy water, which already has a neutron, is not.

In the actual construction of a reactor, thin rods of pure natural uranium perhaps an inch in diameter, encased in aluminum (a weak absorber of neutrons) to prevent oxidation, are inserted into blocks of graphite. Most of the fast neutrons produced by fissions in such a uranium rod escape from the rod into the graphite, and by the time they have traversed this buffer to their next encounter with uranium they are at the thermal speeds that favor their selective capture by U-235. This is the pile type of reactor, so-called because it is a block built up as a lattice of uranium and graphite. While the name "pile" has commonly been used for all types of chain-reacting systems except bombs, "reactor" is now preferred as a more inclusive term, covering the newer types. A reactor using heavy water as moderator, for example, is not strictly a pile but an assembly in which rods of uranium are immersed in a tank of heavy water.

The third basic factor that bars a chain reaction in nature and controls the design of a reactor is the escape of neutrons from the system itself. To retain

SCOPE OF AEC is shown in map and organization chart at right. Map indicates location of major laboratories and other installations, with affiliated universities. All are operated by contractors. AEC plants and suppliers are in 41 of the 48 states.



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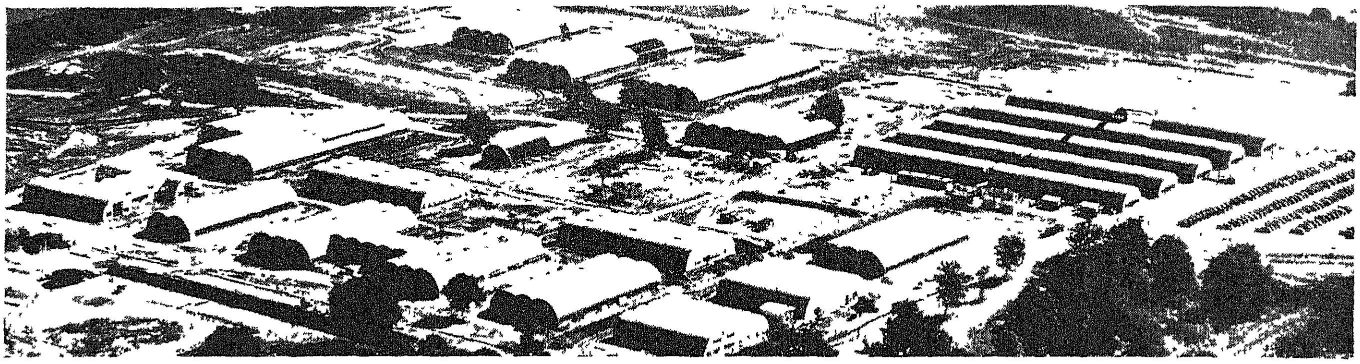


ARGONNE NATIONAL LABORATORY, 30 miles from Chicago, is one of AEC's three general research centers. Shown here are temporary Quonset structures. Permanent buildings are near completion at a nearby site.

enough neutrons to keep the reaction going, the reactor must be built to a certain minimum size, so that the volume in which the neutrons are held is large in proportion to the surface from which they may escape. Obviously the necessary size depends on the shape of the system A sphere, having the smallest surface area for its volume, is the most efficient shape and permits the smallest critical size A cube is nearly as good. The minimum size also is governed by several other considerations—the degree of enrichment of the uranium with U-235, the kind and amount of moderator, the amount of other materials inserted into the reactor, and so on. The critical size of a reactor consisting of almost pure U-235, such as the bomb, may be very small, perhaps the size of a softball, on the other hand some of the low-energy reactors are bulky—of the order of 40 feet in diameter including their seven-foot-thick concrete shielding. Thus size itself is no measure of the power of a reactor.

In an atomic bomb the escape of neutrons presents a special problem, for the neutrons and exploding atoms must be held together long enough for the chain reaction to get well under way before the whole system blows apart. This is accomplished by enclosing the bomb in a casing of very dense material that retards the bomb burst and reflects some neutrons back into the system. This suggests one of the obvious avenues for research in the future development of power reactors the finding of more effective reflectors of neutrons. The invention of a suitable reflecting material that would hold most of the neutrons within the working part of a reactor would not only reduce the critical size of the reactor but would greatly decrease the shielding now required to protect personnel against escaping neutrons. Thus it would enhance the possibility of building compact nuclear engines for ships, planes and vehicles.

Control

The simple principles thus far described are the basis for the design and operation of all present reactors. In operation the pile type of reactor is controlled simply by inserting bars of a material, usually cadmium, that readily absorbs neutrons. By taking neutrons out of circulation, they can bring the chain reaction into equilibrium or stop it entirely The bars slide into pockets in the interior of the reactor. Their insertion and withdrawal is operated by opposing motors, so that very delicate control—to within a tenth of one per cent of the reactor's flux—is possible. A reactor is so sensitive that if it is not airtight even a slight rise in the humidity of the air, resulting in the presence of more neutron-absorbing hydrogen atoms, affects its operation.

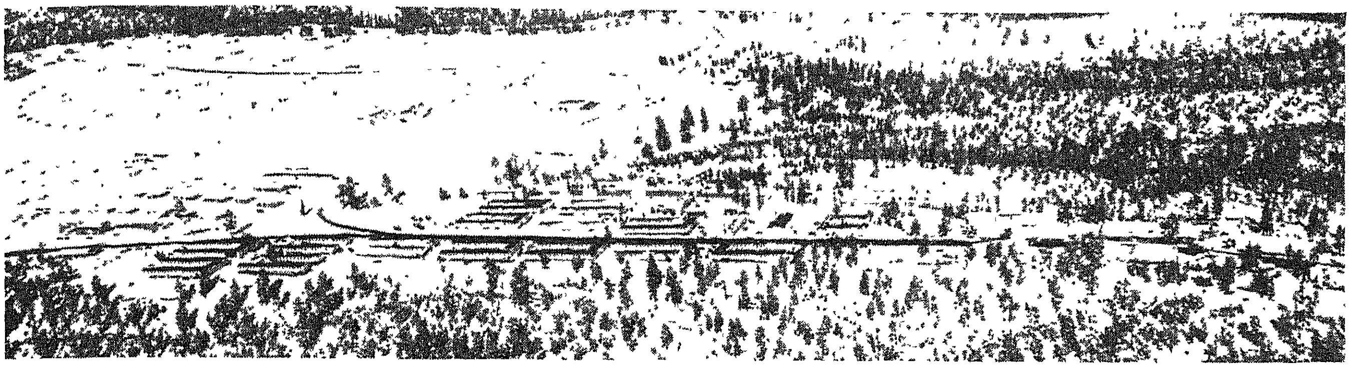
To start the reactor, all the bars are withdrawn. The chain reaction develops rapidly; its control would be extremely difficult but for the fortunate fact that some of the neutrons released by fission—about one per cent—are delayed in emission from a few seconds to a minute. This gives the system enough inertia so that the operator, working with dials that operate the motors, has ample time to bring the controls into play as the reactor heats up. One bar suffices to regulate the level of the chain reaction. When the reaction reaches the desired level, the operator stabilizes it by inserting the bar to a length that soaks up enough neutrons so that from each fission one and only one neutron is captured by another U-235 atom to continue the reaction. The power level of the reactor is determined by the number of atoms fissioning at any moment at that equilibrium stage Reactor technicians designate this rate of operation as the "neutron flux," meaning the number of neutrons passing through a given section of the pile per second. There are several ways of recording the pile's level. The simplest and most commonly used is measurement of its temperature. A pile also contains ionization chambers that indicate the neutron flux. Since such a chamber cannot detect the uncharged neutrons directly, it uses indirect methods; in one instrument the neutrons knock alpha particles out of the chamber's boron lining and these particles ionize argon gas in the chamber In most reactors the ionization chambers, as a safety measure, control extra rods which would drop automatically into the pile if the human operators failed and the reactor rose to a dangerous level. A pile could not possibly approach the energy of a bomb; at worst, if all controls failed and the reactor blew up, it would simulate a rather bad steam-boiler explosion.

Plutonium and U-233

If U-235 were the only fissionable material, there would be no hope for uranium power plants except as an experimental curiosity, the isotope is too rare to be seriously considered as a fuel for economical, large-scale use. The hopes for nuclear power lie in the fact that it is possible to manufacture two other fissionable materials 1) plutonium, derived from U-238, and 2) U-233, a synthetic uranium isotope derived from the heavy natural element thorium.

Plutonium is produced by this series of reactions A U-238 atom, upon absorbing a neutron in a reactor, becomes U-239. This short-lived isotope (half-life· 23 minutes) promptly emits a beta particle (electron) from its nucleus, gains an electron in its outer shell, and is transformed to the artificial element neptunium 239. Neptunium also is unstable (half-life. 2 3 days) and it in turn expels a beta particle, plus gamma rays, and becomes plutonium 239. Plutonium is fissionable in the same way as U-235, when it captures a neutron it splits in two with a vast yield of energy, possibly greater than that from the fission of U-235.

The thorium chain is this. Thorium 232 absorbs a neutron and becomes the short-lived isotope thorium 233 (half-life: 23 minutes), which emits a beta particle and is transmuted to protoactinium 233 (half-life: 27 days), which in turn loses another beta particle and becomes uranium 233. U-233, like U-235 and plutonium, fissions by capture of a neutron. To start this series of reactions, thorium would have to be mixed in a pile with U-235 as the source of neu-



LOS ALAMOS SCIENTIFIC LABORATORY concentrates on weapons research but also does some work in basic physics. Situated on an isolated mesa in New Mexico, it is the most secret of all the AEC installations.

tions. Thus the manufacture of both plutonium and U-233 depends basically upon U-235 as the spark plug. But the great promise of these reactions is that they add comparatively abundant U-238 and thorium to U-235 as potential fuels, and the fissionable materials made from them, once formed, become additional sources of neutrons.

As we have seen, a reactor using natural uranium is deliberately designed to make most of the neutrons by-pass absorption by U-238 in order to maintain the chain reaction. But some neutrons inevitably are absorbed by some U-238 atoms, and there is always at least a small surplus of neutrons that makes this possible without stopping the chain Thus even in a reactor running at a very low power level a little plutonium is created in the uranium rods. To increase the production of plutonium, the power level must be raised: obviously the greater the number of fissioning atoms, the more plutonium will be made. This is the basis of operation of the plutonium-producing piles at Hanford. They are built of pure natural uranium and graphite, like other thermal reactors, but run at considerably higher power levels. Periodically the uranium rods are removed and the plutonium in them is extracted by chemical methods.

Types

The Atomic Energy Commission now has eight known reactors of various types (besides its bombs). The oldest, originally built behind the University of Chicago stadium but later transplanted for use in research to the Argonne National Laboratory 30 miles from Chicago, is a low-energy pile of uranium, uranium oxide and graphite. Its maximum power is 200 watts. Because it has no cooling system, its temperature is never allowed to rise above 50 degrees Centigrade. The next oldest reactor is the slow-neutron pile at Oak Ridge, used for research and the production of radioactive isotopes. It has a power capacity of about 2,000 kilowatts and can go from room temperature to 600 degrees Centigrade in a few seconds, although it is never operated at that hot level Its greater power is made possible by an internal air-cooling system The three plutonium piles at Hanford, whose power level has not been disclosed but is certainly no less than 5,000 kilowatts, are water-cooled—an inefficient method because the circulating water in the piles absorbs many neutrons, but the most practical one available to remove the large quantities of heat. The Hanford piles, like those at Argonne and Oak Ridge, are lattices of natural uranium and graphite and use slow neutrons.

The Commission's three other present reactors are experimental One is a heavy-water affair at Argonne. Another is the so-called "water boiler" at Los Alamos. This small reactor contains a solution of an enriched uranium salt, presumably in heavy water, in a vessel made of neutron-reflecting material. It is a "homogeneous" reactor, that is, the fissionable material is mixed with the moderator and distributed uniformly throughout it. It may be controlled, like other reactors, by the insertion of neutron-absorbers (Some reactors are controlled simply by moving pieces of reflector or moderator.) The third experimental reactor, also at Los Alamos, is fueled by plutonium, with no moderator. Thus it operates on fast neutrons, and approaches the conditions in a bomb—its reacting section is only a foot or two in diameter. Its chain reaction is kept under control, however, at a very low power level. For reasons that will be considered presently, research with this fast reactor has provided some of the most valuable leads thus far toward the design of a power reactor.

The Power Conundrum

By now the dimensions of the power problem begin to become apparent. It is easy enough to calculate that one pound of fissionable fuel contains 10 million kilowatt-hours of energy and is the equivalent of 2.6 million pounds of coal. It is even no great feat to design the outline of a fission power plant: One simply constructs a hot reactor enclosed by a reflector and shield, pipes a coolant (cooling fluid or gas) through it to extract the heat, and transfers the heat to a boiler and steam turbine or a gas turbine. But there are certain difficulties about details.

For instance, the reactor must be raised to temperatures far above any yet attempted under control. Even the "hot" piles at Hanford operate well below the boiling point of water. By attaching the necessary heat-exchanging equipment to one of these reactors and allowing it to go to a high level, power might be generated to light an electric-light bulb or perform a slightly more burdensome task. But it would be the labor of a mountain to produce a mouse. And it would ruin the pile.

The paradox of the vast energy in uranium is that its very concentration constitutes one of the prime problems in extracting power efficiently from it. Its power potential is fantastic; in a bomb the temperature produced is measured in millions of degrees. But pound for pound uranium is the most expensive of all possible fuels, and its use is prohibitive unless a way is found to apply an appreciable part of the power it is capable of producing in a small space. This raises a number of serious difficulties. One is the heat question. Obviously, to approach any reasonable efficiency in the extraction of nuclear energy means going to very high temperatures. But the vulnerability of materials to heat imposes a relatively low limit on practical operation. The most resistant known materials will tolerate no more than 2,000 degrees Fahrenheit Reactor designers must consider the effects of heat on all the reactor ingredients—pipes, coolant, moderator, controls, reflectors, the fuel itself. Even more troublesome than the heat problem is the fact that the high neutron flux that develops in a hot reactor also is destructive to materials, especially metals. And materials that may tolerate high temperatures do not withstand particle radiations. All these lessons were expensively learned in the experience with the Hanford piles, which approached a breakdown after the war.

Still another materials problem is that

introduced by contamination of the reactor with the pipes and coolant necessary to extract its heat. They divert neutrons from the chain reaction Even if materials that absorb few neutrons are found for these purposes, at best they will impair the reactor's delicately balanced neutron economy.

Thus the materials question injects a whole galaxy of new problems into power-reactor construction The answers will require not only engineering studies but new fundamental knowledge in physics and chemistry. Kenneth S. Pitzer, director of the AEC's Division of Research, observed: "We need entirely unprecedented materials, not merely improvements of those already known."

Yet materials constitute but one of many hurdles that must be cleared to make a power reactor economically feasible. Just as important is the conservation of the costly uranium fuel. A reactor run at a high level quickly becomes poisoned by its own fission products. They absorb neutrons. Moreover, in a natural uranium pile operated for power the proportion of U-235 would soon drop to a level where it could not maintain a profitable chain reaction in the contaminated fuel. The poisoned and diluted uranium probably would have to be removed after but a small part, perhaps one per cent, of its fissionable atoms had been used. Should the uranium be reprocessed by chemical removal of the fission products and returned to the pile? That would be a costly process, because the chemical treatment of the highly radioactive material must be carried on by remote control. Should the reactor be enriched with booster portions of fissionable material? Should it be operated on slow neutrons, intermediate neutrons (less moderator) or fast neutrons (no moderator)? These are the principal questions that the Commission is now about to investigate.

Breeding

The answers to most of them may be provided by tests of an idea on which AEC is staking most of its hopes—a "breeder" reactor that would produce new fissionable atoms as fast as it used the old ones up. This is still only a theoretical concept, but hopes are encouraged by preliminary studies of the idea in the fast reactor at Los Alamos. The theory rests on the fact that when a U-235 atom fissions, at least two neutrons are produced. The precise number is a secret, but the AEC has stated that the average is between two and three; the possibility is not excluded that it is more than three. Suppose that a reactor could be built so efficiently that from every fission two neutrons were available for useful capture. One would be taken by a U-235 atom and produce a fission and energy. The other would be absorbed by a U-238 atom and produce an atom of fissionable plutonium. Thus the reactor, while producing energy for power, would constantly replenish the supply of fuel and source of neutrons. If more than two usable neutrons could be realized from each fission, the reactor would actually produce more fissionable material than it consumed. The AEC has aptly named the idea "Operation Bootstrap."

In such a reactor a blanket of natural uranium around the fissioning material would absorb the excess neutrons and be converted into fuel. By recovering the fissionable plutonium so manufactured and adding natural uranium to the reactor from time to time, it would be possible to keep the reactor going indefinitely. And thorium would serve as well as uranium, for the original capital investment of fissionable U-235 or plutonium could be used to convert thorium into U-233, which in turn could continue the transformation of thorium into fuel.

The AEC's General Advisory Committee of scientists has reported, however, that "the engineering difficulties associated with breeding are enormous" To achieve the goal of two usable neutrons per fission would require reducing neutron losses in and from the reactor to an extremely low level. On the other hand, the requirements for a power reactor—high operating level, coolant system, and so on—tend to increase the loss of neutrons. Moreover, the chemical recovery of the new fuel bred in the uranium or thorium blanket would be no small job. The radioactive metals must be treated behind heavy shielding by remote control; recovery of the fissionable material must be virtually complete at each stage to maintain the level of original capital in the pile; and the treatment must be repeated many times until the fuel is completely consumed. There is also the problem of the removal of fission products from the power-producing part of the pile. And finally there is the question of managing the neutrons so that half are captured by fissionable atoms and half by U-238 or thorium atoms.

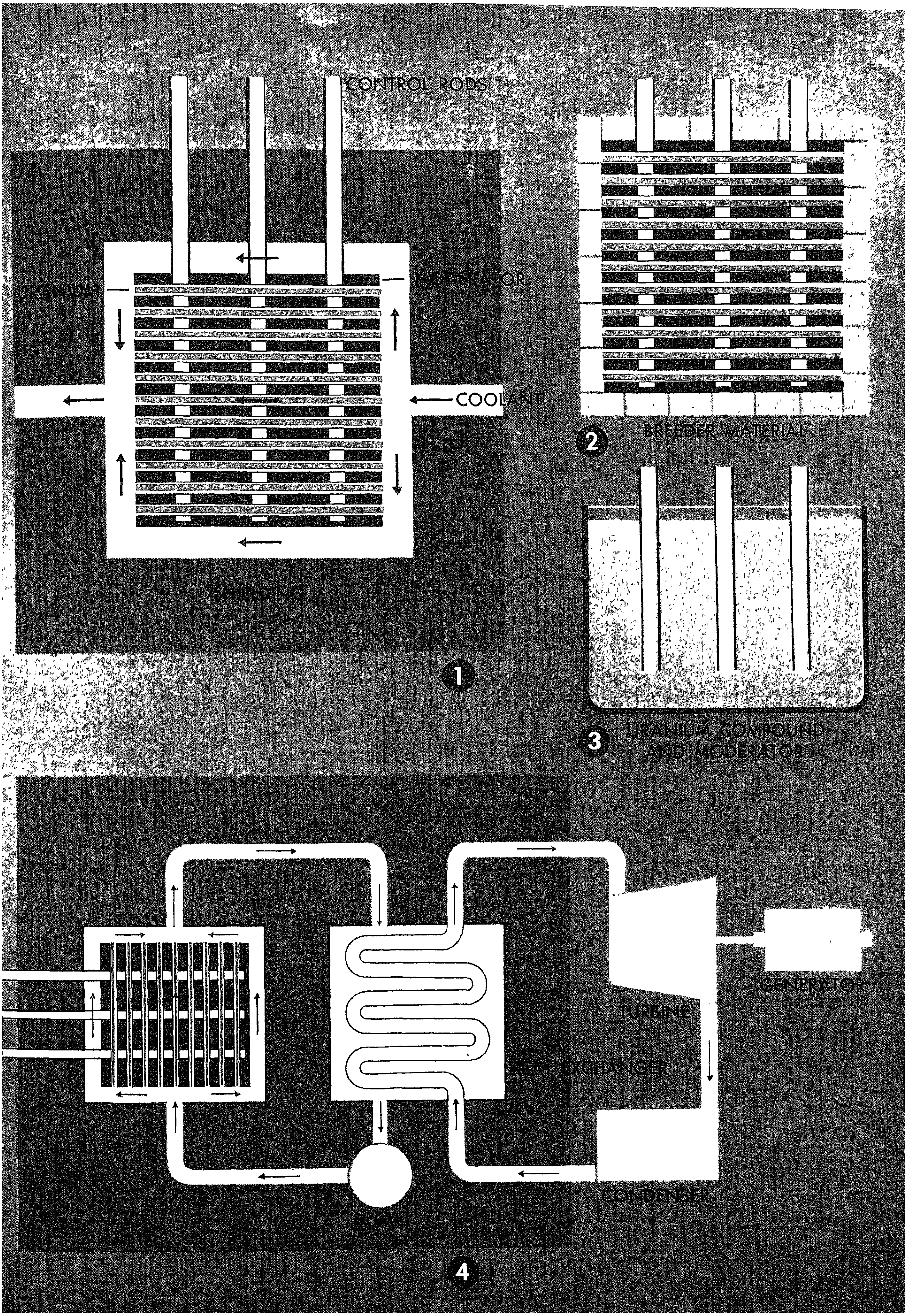
All these manifold problems help to account for the AEC's long hesitation about undertaking a specific project. A reactor is expensive to build: about $25 million in round figures. In the absence of an emergency such as justified the bomb, or of public awareness or concern about the problem, the Commission has been slow to decide on costly, uncertain experiments. In a field still characterized by few facts and many theories, the scientists, engineers, military men, contractors and administrators within the AEC have had sharp differences over plans and proposals, with the result that some of the ablest reactor investigators have resigned from the project. Early this year the Commission determined to make a beginning, however modest in aim. To head the reactor program it enlisted Lawrence R Hafstad, a Carnegie Institution nuclear physicist who worked on the proximity fuse at Johns Hopkins University during the war and came to the AEC from the military Research and Development Board It allotted $120 million to the reactor program and decided to go ahead with the construction of four power reactors. None of the four promises to produce economical power, the hope in these experimental models is simply to show that usable power can be achieved and to learn how to go on from there. Two or three of the reactors will be built in a huge, isolated testing area of 400,000 acres just acquired by the AEC near Pocatello, Idaho. The fourth will be constructed by the General Electric Company as contractor at West Milton, near Schenectady, N. Y. The research center for the whole AEC reactor program is at the Argonne National Laboratory, operated by the University of Chicago.

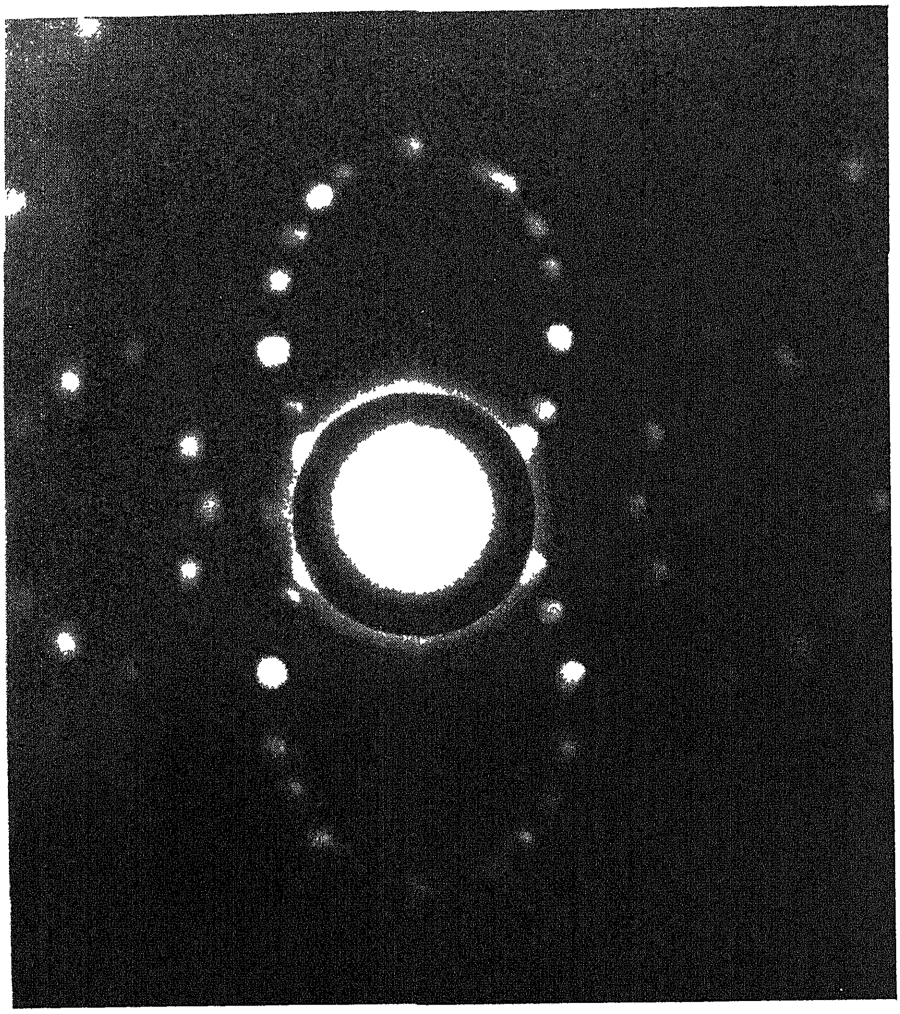
The Four Projects

The first project is a materials testing reactor to be built by Argonne in Idaho. Its purpose will be to investigate the reactions of a great variety of possible reactor materials to an intense neutron flux, far higher than that in the Hanford piles. To reduce the problem to the single variable of radiation effects, this reactor will not test the effects of heat, it will be cooled to moderate temperatures by rapidly circulating water. It will use enriched fuel, providing a surplus of neutrons so a great deal of test material may be loaded in its pockets without stopping the chain reaction. It may also be the first reactor to use beryllium as a moderator—an important point to investigate because graphite and heavy water appear unsuitable as moderators in a high-power reactor. The materials reactor is expected to be completed by 1952.

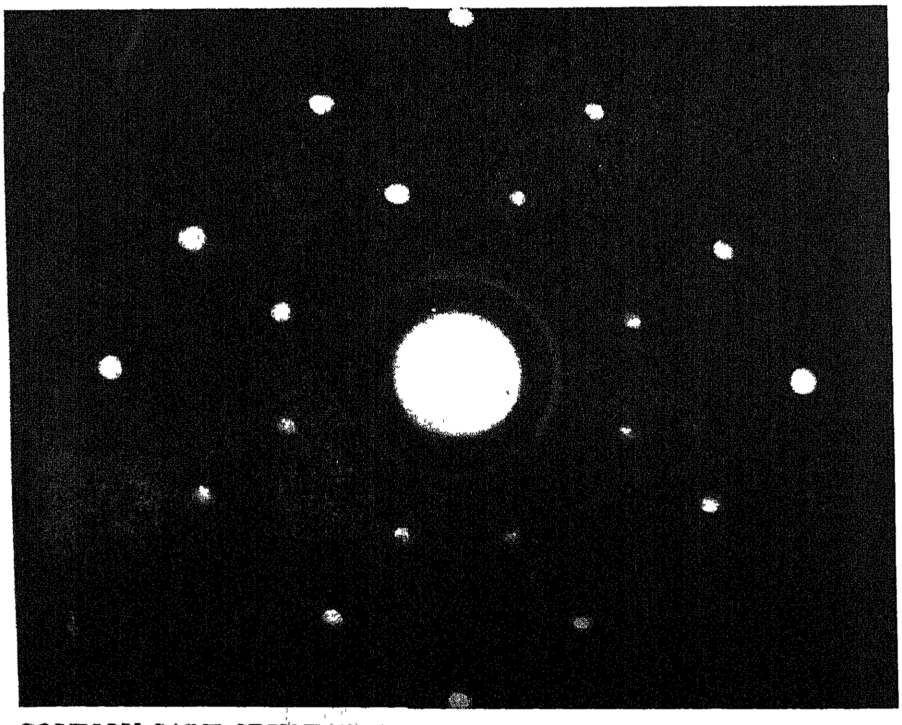
The second reactor is military: a

REACTOR PRINCIPLES are illustrated in these schematic diagrams. Basic pile type of reactor (1) is a lattice of uranium slugs, shown in red, and graphite blocks, with cadmium or boron control rods and circulating water or air as coolant to prevent overheating. Proposed breeder reactor (2) would have a blanket of natural uranium or thorium blocks, shown in pink, which would be converted to fuel. "Homogeneous" reactor (3) has uranium salt and moderator mixed together in solution. Proposed power reactor (4) will circulate liquid metal coolant through hot pile and then to heat exchanger, there heating steam to run turbine and produce electricity.


CONTROL RODS
URANIUM
MODERATOR
COOLANT
SHIELDING
1
BREEDER MATERIAL
2
URANIUM COMPOUND
AND MODERATOR
3
GENERATOR
TURBINE
HEAT EXCHANGER
CONDENSER
PUMP
4



NEUTRON DIFFRACTION technique, developed by AEC workers, is illustrated by these striking Laue photographs of crystals. Above is picture of quartz structure. The method provides a new tool for study of molecules.



COMMON SALT CRYSTAL (NaCl) made this photograph. Because neutrons are scattered only by the nucleus of an atom, they can show the molecular position of a light atom (e.g., hydrogen) undetectable by X-rays.

nuclear motor for the Navy, to be designed by the Argonne Laboratory and built in Idaho by the Westinghouse Electric Corporation. Using enriched uranium as fuel, it will operate at some 60,000 kilowatts and at a high temperature, possibly 2,000 degrees F. The plant is to be a prototype for a ship's engine. Its design is still in early stages, but there *has already been considerable discussion* of its possibilities Its most likely use would be in a submarine. A single charge of nuclear fuel could propel a ship for tens of thousands of miles. Since the motor would need no oxygen, a submarine could cruise under water for months The great weight of batteries in a conventionally powered submarine would be eliminated, and it has been suggested that the sea water normally carried in its ballast tanks could serve as part of the necessary shielding for the radioactive motor. This reactor will cost some $30 million. The Commission's decision to undertake a reactor for the Navy rather than one for a bombing plane as its first military project was dictated by the inescapable logic of the problem—before one can build a nuclear motor light enough to be carried in a plane, it is necessary to find out whether a workable motor can be built at all.

Even if it succeeds, however, the naval reactor at best will be a forced plant, possibly justified by military needs but fantastically uneconomic for any other purpose. The prospects for practical power will depend mainly on the Commission's two other reactor projects, both of which will test the breeding principle.

The first of these is a fast reactor, using enriched uranium fuel and no moderator. Such a reactor offers the best possibilities for breeding because it promises the smallest neutron losses within the system. It will use a new type of coolant for the transfer of its heat. Water obviously is out of the question, not only because it absorbs neutrons but also because in a high-temperature reactor it would become high-pressure steam. That would demand thick pipes, resulting in greater loss of neutrons, and would compound the corrosion problem. The most promising coolant appears to be a liquid metal—one that liquefies at a relatively low temperature and absorbs few neutrons. These specifications are met by sodium, bismuth or lead. The metal, after being heated in the reactor, will flow through coils in a water boiler, heating steam which will be used to produce electricity. Since little or no radioactivity will be transferred from the metal to the water, the steam turbine will need no shielding.

A fast reactor, however, has an important defect as a power source: it yields its energy in too small a space. Comparatively little pipe surface could be packed into it for the transfer of its

heat to the coolant. An attempt to remove this difficulty will be made in the fourth reactor, to be built by the General Electric Company. It will be an intermediate reactor, using little moderator and neutrons of intermediate speed. It will be considerably larger than the fast breeder, and will operate at a lower temperature, in the range of 400 to 1,000 degrees F This reactor will cost about $18 million and may be completed in 1952. Most of the Commission's hopes for demonstrating the practicality of atomic power are riding on this project. But it is a fundamentally new experiment. no reactor has yet been built to operate in the intermediate-energy range While neutrons of intermediate speed favor the breeding of fissionable material, they are unfavorable to fission and a chain reaction, the problem will be to design the reactor so that the fuel can capture enough neutrons to maintain the chain. It will use enriched fuel.

How Much Fuel?

Is there enough available uranium in the world to make the struggle to develop its power potentialities worth while? Investigations indicate that the answer is clearly yes. If breeding works, all of the fairly abundant U-238 and thorium that can be extracted from the earth can be converted into fissionable fuel. The known deposits of uranium ores of commercial grade (at least one per cent uranium) contain an estimated 100 million pounds of uranium—in terms of contained energy that would be enough to supply the entire power needs of the world for at least 50 years at the present rate of power consumption from all sources In addition, the earth contains an equal amount of available thorium. Uranium and thorium together represent a potential wealth of power greater than the world resources of petroleum. If methods were found for using low-grade ores, they might even exceed the power potential of the earth's coal.

In view of the multitude of unsolved problems that stand in the path to nuclear power, attempts to forecast whether uranium will compete as a fuel with coal obviously can be little more than guessing games. Early post-bomb estimates by engineers calculated the cost of nuclear power at from 4 to 10 mills per kilowatt-hour, which would place uranium almost on a par with coal and give it an advantage in areas remote from coal sources. But these computations admittedly were based on extremely meager data. There are persons close to the atomic energy program who believe that at best the power project will be an interesting and costly experiment, possibly demonstrating that power reactors may be usable for certain special purposes, but unlikely to prove that uranium is feasible as a common source of energy. Among those who hold this view is J Robert Oppenheimer, the wartime director of the Los Alamos group that produced the bomb, and now the chairman of the AEC's General Advisory Committee.

Yet to dismiss the possibility of the constructive use of atomic power at this stage would be as pointless as it would have been a century ago to dismiss Michael Faraday's discovery of the induction of electric currents. The one certainty in science is that it is unpredictable, and the solution of the atomic power problem may well lie along roads still unseen The discovery, for example, of large-scale uses for the troublesome radioactive fission products would go a long way toward reducing the power cost; properly safeguarded, they might perhaps be used for energy, for killing bacteria, as industrial tracers, and so on. Some investigators envision a homogeneous reactor, on the principle of the "water boiler" at Los Alamos, that would produce power, manufacture fissionable material, reprocess the fuel and remove wastes—all in one continuous circulating system. Some even dream of short-cutting most of the problems by finding a way somehow to convert the nuclear radiations in a reactor directly into electricity instead of heat.

At all events, no one in the AEC doubts that the U.S. should push the further exploration of atomic energy with all possible speed, if for no other reason than that other nations are doing so The British, who have a 6,000-kilowatt pile, known as Bepo, are believed by some to be ahead of the U.S. in the study of the power problem. Already there are four known research reactors in operation outside the U.S.—one at Chalk River, Canada; two at Harwell, England; and one near Paris, France. And, as Arthur Holly Compton, Chancellor of Washington University, observed recently, it would not be surprising if the Russians also had at least one operating reactor.

The reactor program has been discussed at some length because it is the heart of the whole atomic energy enterprise—if one thinks in terms of peace rather than war. From that point of view the "atomic age" is still in the future. The AEC hopes to produce a functioning power reactor in five to 10 years and an economically practical one in 20 years. Whether it will achieve that aim may depend as much on politics as on research. For it is idle to pretend that atomic bomb-making does not seriously impede the development of atomic energy for peaceful purposes. "Guns-or-butter" issues arise at many points—in the budget, the use of uranium, the recruitment of personnel, security restrictions, the control of research. The specific conflicts can be seen by examining the AEC operation.

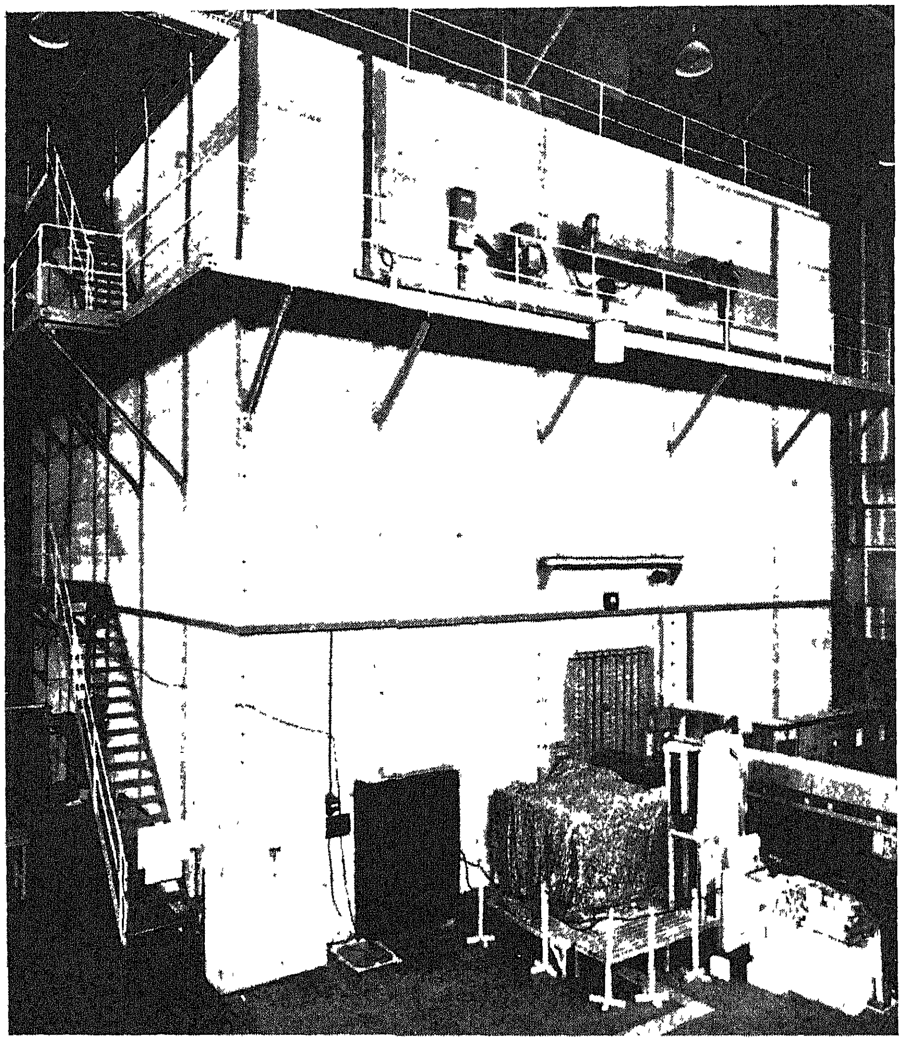
From the Congo to Los Alamos

The Atomic Energy Commission is a peculiar hybrid compounded of many contradictions The basic one is that it is a civilian agency whose principal concern is making weapons. Theoretically an independent body, it is under close surveillance by a special Joint Committee of Congress, is linked directly to the National Military Establishment through a Military Liaison Committee, and in addition is watched over by an independent General Advisory Committee appointed directly by the President. Most unusual of all, it is a Government enterprise that delegates nearly all its work to independent operators—as if the Post Office Department were to farm out the management of post offices to private contractors. All of the Commission's important installations, even its scientific laboratories, are operated by industrial or university contractors. Of the 68,000 persons working in the atomic energy undertaking, only 4,500 are direct employees of the Commission; the rest work for the contracting operators.

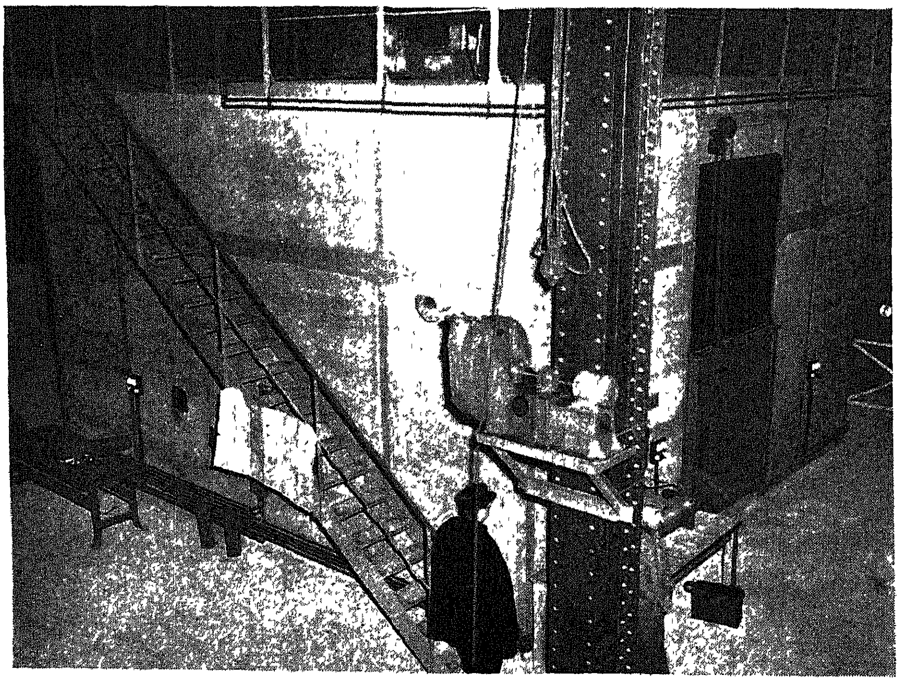
The AEC project is a vertical operation, covering the whole range from raw materials to finished product. It begins with the procurement of uranium ore. The three most important uranium sources in the world are at Joachimsthal, Czechoslovakia, in the Belgian Congo, and at Great Bear Lake, Canada. It is no secret that most of the AEC's uranium has come from the rich Shinkolobwe mine in the Belgian Congo, with the Eldorado mine at Great Bear Lake as a second source. The pitchblende ores of the Shinkolobwe assay up to 50 per cent uranium; those of the Eldorado, 10 per cent The U.S. itself has no known deposits of high-grade ore. The carnotite rocks of the Colorado Plateau, the only U.S. source of any consequence, contain at best only about one tenth of one per cent uranium. To spur the search for domestic uranium, the AEC has recently opened a field office at Grand Junction, Col., and has offered a bonus of $10,000 for the discovery of high-grade deposits.

The next stage in the AEC chain of operations is purification of the uranium, not to ordinary industrial standards but to pharmaceutical standards of purity, with impurities only a few parts per million. More than 30 contractors in many cities are engaged in this work, turning out pure uranium by the ton. The principal plants are at St. Louis, Cleveland and Niagara Falls.

Their product goes to the AEC's two huge plants for the production of fissionable materials for bombs. These are Hanford's plutonium-producing piles



BRITISH REACTOR is called Gleep for graphite low-energy experimental pile. In the face on the right are holes, or "ports," for samples of material which are inserted in pile for irradiation to make radioactive isotopes.



FRENCH REACTOR uses uranium oxide as fuel and heavy water as moderator. It operates at very low power and can be utilized only for research. Its principal function is to provide neutrons for study of their various effects.

and Oak Ridge's K-25, the gaseous diffusion plant that separates U-235 from U-238. The feed material for the piles is pure uranium metal, for the gaseous diffusion process it is uranium hexafluoride (UF_6). The gas is blown through a series of thin porous barriers with extremely fine holes. At each barrier, the U-235 atoms, being lighter and therefore faster, get through more rapidly than U-238. Hence successively richer concentrations of U-235 are segregated To achieve the enrichment necessary for a bomb, a given batch of feed material must be cycled through at least 4,000 barriers, a process that takes months. Nevertheless the gaseous diffusion method has proved to be the best and least costly of the several U-235 separation processes developed simultaneously during the war. The $350 million electromagnetic separation plant at Oak Ridge, known as Y-12, which produced U-235 for the first bomb, was shut down a year and a half ago and now houses biological laboratories. The AEC is building a large addition to K-25 and planning still another gaseous diffusion plant. And at Hanford it is also constructing new plants, doubling the $350 million wartime investment in that installation. Since it took over from the Manhattan District, the Commission by improving efficiency and expanding plants has substantially reduced the cost and increased the production of fissionable material.

Theoretically the mounting stockpile of U-235 and plutonium is equally usable for peaceful or military purposes, and might some day be translated from swords into plowshares Actually, however, it is produced at a cost that can be justified only by military needs. The *production methods required to produce* bomb material are so wasteful that they reduce rather than increase the store of potential uranium fuel. The U-238 that remains when U-235 is separated from it is merely a waste product; it has lost its value as a possible fuel unless recombined with U-235. Similarly, in the production of plutonium in the Hanford piles most of the U-238, and even of the U-235, is lost. After a relatively small proportion of the U-235 in a uranium rod has fissioned to produce plutonium, the plutonium is extracted and the remaining uranium, contaminated with fission products, is buried as waste. It is questionable whether it will ever be worth while to reclaim this material for use in a power reactor. In short, the atomic bomb program has simply skimmed the cream from the huge amounts of uranium it has consumed. This cream, if released to pacific purposes, might be used to enrich the fuel in power reactors, but it would be an extravagant method of enrichment.

The final stage of the AEC production chain is, of course, the development

and manufacture of bombs at Los Alamos. By unflagging research the Commission has substantially increased the power of the bomb; its new designs were successfully tested at the Eniwetok Proving Grounds last year In the coming year the Commission will spend $210 million for the further development and manufacture of bombs, plus $300 million for the production of fissionable materials. Although the rate of production of bombs is one of the most carefully guarded of the AEC's secrets, it can be a secret only in detail On the basis of known and unconcealable facts about production methods, any knowledgeable physicist or engineer can make a shrewd guess, with confidence that his guess is not wrong by a large factor, that the AEC is probably producing a ton or two of fissionable material, perhaps enough for 100 to 200 bombs, per year.

Effects of Radiation

Besides bombs and reactors, the Atomic Energy Commission has a third concern which is inherent in its assignment the effects of nuclear radiations as a new factor in the human and natural environment. The Commission is studying this phenomenon at every scientific and technological level. At Oak Ridge its biologists are examining the effects of neutron and gamma radiations on the chromosomes of the most elementary organisms, and on the protoplasm and physiology of mice and rats, some of which they are exposing to the intense flux in the interior of the uranium pile. At Brookhaven researchers in various sciences will investigate the results of the operation of a reactor on every aspect of the surroundings: the atmosphere, soil, ground water, rocks, natural animal life, and so on. The object will be to determine safe levels for the discharge of radioactive gases from a reactor smokestack and safe methods for the burial of wastes. At a number of universities workers under contract with the Commission are studying the effects of long-continued, low-level radiation on plants and animals, the genetic results of radiation and a host of other problems. At the University of Rochester biochemists are testing various drugs and hormones as treatments for radiation sickness. In Japan AEC investigators are conducting a long-term study of the Hiroshima survivors. And at various centers in the U.S AEC consultants are considering defenses and protections against atomic bombs.

Provider for Science

In the opinion of Lilienthal and his colleagues, the AEC's assignment does not end with matters directly related to uranium fission. Broadly speaking, "atomic energy" can be construed to embrace all of nuclear physics and large areas of the other physical and biological sciences—and the AEC has so construed it. On the theory that the nation's economic and military strength depends not only on atomic armament but also on scientific and technological progress "right across the board," the Commission is supporting an astonishingly broad spectrum of research. Its pending budget proposes to provide $55 million for physical research and $33 million for work in biology and medicine in the coming year. The greater part of this will be spent for the construction and operation of its own laboratories, but some $20 million will go to universities. Most of the AEC's university grants are distributed through the Office of Naval Research (SCIENTIFIC AMERICAN, February) for basic work in science The extent to which physics in the U.S. now is dependent on AEC support is indicated by the fact that a majority of the papers published in physical journals represent work done in AEC laboratories or by its contractors.

The range of the AEC's interests can best be shown by mentioning some of the activities of its principal laboratories:

Oak Ridge National Laboratory, operated by the Carbide and Carbon Chemicals Corporation, is the site of the AEC's most important contribution to science thus far. the manufacture of radioactive isotopes. From Oak Ridge more than 5,000 shipments of isotopes have been distributed to researchers and physicians throughout the U.S. and in 21 foreign countries. Its reactor is also a busy center of neutron research. The famous south face of the pile is festooned with instruments and experiments. One of the most exciting is E. O. Wollan's and C. G. Shull's study of molecular structure by means of the technique of neutron diffraction, which for the first time has made it possible to determine the position of a light atom such as hydrogen in a compound molecule. At Oak Ridge has been developed much of the new science of radiochemistry—the chemical behavior of radioactive elements and compounds. In its biological laboratories studies are being conducted not only of radiation effects but of photosynthesis and other basic phenomena. A new research device at Oak Ridge and at the Argonne Laboratory is the so-called "isotope farm," where radioactive material is fed to foxglove to produce radioactive digitalis, to poppies to yield radioactive morphine, to animals to synthesize radioactive insulin

Argonne National Laboratory, operated by the University of Chicago, is principally concerned with research on the design of new reactors. But it also has large physical, chemical and biological laboratories, for which new buildings are now under construction. Nearing completion is a four-million-volt Van de Graaff generator for basic nuclear studies.

Brookhaven National Laboratory on Long Island, operated by a group of nine northeastern universities, is projected as the foremost AEC center for fundamental research It will have a 5,000-kilowatt reactor, now almost completed, designed specifically as a research tool, a 3.5-million-volt Van de Graaff generator, a 30-million-volt cyclotron, and a massive proton-synchrotron, which the laboratory calls the "cosmotron," that will accelerate protons to the stupendous velocity of two to three billion electron volts. Though Brookhaven is still in swaddling clothes, it has already begun some interesting studies of cosmic rays, radiation effects, new instruments

Los Alamos Scientific Laboratory, operated by the University of California, is primarily concerned with the design of weapons, but it has pursued a number of investigations of the most fundamental character in nuclear physics Its physicists were the first to liquefy and study the properties of the rare isotope helium 3 Just to make sure that the AEC is not overlooking the possibilities of chain reactions other than from fission, they have been dabbling in the study of nuclear reactions among the light elements. The Los Alamos physical laboratory, described as one of the best equipped in the world (no outsider is permitted to enter it), has two research reactors, a cyclotron, a betatron, a Cockcroft-Walton accelerator, a 2.5-million-volt Van de Graaff accelerator, a 12-million-volt Van de Graaff abuilding, and a staff of some 1,600 scientists and technicians.

University of California Radiation Laboratory, operated by the University as an AEC research center, contributes to the Commission's nuclear studies the world's most powerful existing accelerator, California's 300-million-volt cyclotron. The Commission's plentiful funds will also make possible the building of California's far more ambitious project—a $9 million proton synchrotron designed to bombard nuclei with particles of six to 10 billion electron volts.

Ames Laboratory, operated by Iowa State College, is the chief AEC center for research in the metallurgy and chemistry of uranium, thorium, beryllium and other basic reactor materials. It is doing some pioneer probing into the rare earths (which incidentally are neither rare nor earths)—elements that appear as fission products and show some promise as metal alloys.

In addition the AEC has a number of other laboratories, either directly under its supervision or working on large contracts for it: at the Hanford Plutonium Works, operated by the General Electric Company; at the University of Roches-

ter, at General Electric's Knolls Atomic Power Laboratory.

Thus the Atomic Energy Commission offers to science and technology unprecedented machines, facilities and opportunities Only in its laboratories can physicists work with reactors, with plentiful sources of neutrons and with some of the strange new techniques and instruments born of atomic energy. The AEC also proffers other attractions—better pay than in a university (for young scientists), opportunity for full-time research without teaching duties, ample funds for experiments. Yet the AEC does not especially attract scientists, and its greatest single problem is the difficulty of recruiting able workers and administrators. Few first-rank scientists have remained in the project University science and engineering departments have observed that their young graduates seem to prefer a university post to working for the Atomic Energy Commission. And although the AEC has urged university scientists to make use of its laboratories, relatively few have availed themselves of the invitation.

Secrecy

Unquestionably one of the important reasons is the secrecy that hangs over the project. The Commission has made resolute efforts to ameliorate this forbidding atmosphere. In the past year it has noticeably improved the morale of its staff. It has sought to make life in the AEC communities more nearly normal and to carry out the injunction in the Atomic Energy Act to promote "that free interchange of ideas and criticisms which is essential to scientific progress." It has encouraged its researchers, past and present, to publish their non-secret work, though with less than perfect success; a vast amount of old work which no longer affects security remains unpublished simply because its authors have not taken the trouble to get it declassified. The Commission also recently established unclassified areas in basic science, permitting free communication in these fields without censorship. These areas, which clearly involve no danger of breach of security, include mathematics, theoretical physics except as it applies to fission and weapons, the physical properties (except nuclear) of the elements below 90 (thorium), the basic chemistry and metallurgy of elements below 83, the design and use of nuclear instruments such as accelerators and radiation detectors. (The manufacture of the latter is now an active, $4 million-a-year U.S. industry.) In addition, many phases of fission and reactor theory are now declassifiable.

Nevertheless, the AEC's security controls remain severe and omnipresent. Recent newspaper headlines to the contrary notwithstanding, the Commission has policed the project more strictly than the Army did during the war. Of the Commission's 4,500 employees, no fewer than 1,800 are security officers, employed full time as guards, escorts, and so on. Its contractors also have their own security organizations. The Commission has instituted strict accounting systems for its documents and materials. In most AEC laboratories, offices and other installations, no visitor may move anywhere, even from one office to the next, without an escort. Three quarters of the research in the Commission's laboratories is secret: of some 2,000 reports made by its scientists last year, nearly 1,700 were classified. To clear a research worker or consultant for access to classified AEC data or areas requires an FBI investigation, and the process takes at least three months. It is all but impossible to obtain clearance for a scientist who is not an American citizen—or who has a relative with a record of radical activities Typical of the rigor of the security regulations is the case of a recent application for a research grant The applicant, who had previously done secret work, unthinkingly stamped his application "Secret" It took a month for the Research Division at AEC headquarters in Washington to get the document declassified and to discover by inquiry that the study the applicant proposed to make involved no secret information.

The money cost of all this secrecy is substantial. the Commission has spent millions of dollars for fences alone. The cost in inconvenience and the isolation of the atomic energy project from industry and the general community of science is incalculable. An Industrial Advisory Group recently surveyed the project at the Commission's invitation to determine how U.S. industry might take a more active part in atomic energy developments. It reported that the "burdensome" security regulations constituted a "formidable impediment to any attempt to study and understand the enterprise," and to the enrichment of U.S technology by the engineering inventions developed in the project.

The impediment is less apparent in science than in technology, for most of the basic knowledge in nuclear and allied science cannot be and has not been secret. Communication among scientists in the fundamental disciplines is comparatively free. Nevertheless the climate of secrecy is infectious, and its encroachment upon pure science is not inconsiderable. One of the many small but significant examples is the fact that the X-ray laboratories at the AEC's University of Rochester center are a restricted area, for no reason that anyone can explain The Commission has been increasingly aware of the subtle form of paralysis that stems from secrecy, and of the truism that when one locks a laboratory he locks out more than he locks in. The history of science possibly contains no more ironic example demonstrating this truth than an incident that occurred within the atomic energy program itself. One of the most important events in physics since the war was the creation of artificial mesons in the cyclotron of the University of California Radiation Laboratory Yet the event was not known to the laboratory physicists when it took place, its discovery came about through the visit of an outsider—and a foreigner at that. Not until the brilliant young Brazilian investigator of cosmic rays, C. M G. Lattes, advised the laboratory workers on how to develop their photographic emulsions did they learn that the cyclotron had been manufacturing mesons for months without their knowledge.

The Quandary of Scientists

The paradox of secrecy is that the further it spreads the more it defeats its own purpose. The real secrets in the atomic energy program are the engineering and chemical processes for the purification of uranium, the separation of U-235, the extraction of plutonium and the design and construction of the bombs. Yet for self-protection against politicians alert for the betrayal of fancied secrets, the Atomic Energy Commission not only must guard what is actually secret but is forced to create a bureaucratic structure of security that is in the highest degree distasteful and discouraging to prospective recruits. To submit one's private affairs and family to investigation by the FBI, to cut oneself off from full communication with one's fellows in science, to place oneself at the mercy of Congressional demagogues, to live with what a great scientist formerly in the project describes as "a constant creepy feeling of being under surveillance"—these are hardly invitations to a career. It is small wonder, therefore, that the atomic energy enterprise has little appeal for many scientists. At its most extreme, the revolt of scientists finds a symbolic expression in the great Austrian physicist and Nobelist Wolfgang Pauli, author of the "exclusion principle," who sat out the war at the Institute for Advanced Study in Princeton, steadfastly refusing to listen to any secrets or to have anything to do with secret projects At the end of the war he withdrew to the peace and quiet of his professorship at the *Technische Hochschule* in Zurich, Switzerland (he will return to the Institute next fall).

Of the leaders in science who were associated with the making of the bomb, nearly all have now retired to more pleasant work. J. Robert Oppenheimer is director of the Institute for Advanced Study. Harold Urey is investigating the radioactivity of fossils and the temperatures of ancient seas. Leo Szilard has abandoned nuclear physics for the study

of bacteriophages Willard Libby, of the University of Chicago, is studying the radioactivity of Egyptian mummies. Enrico Fermi, Hans Bethe, Eugene Wigner, Philip Morrison, J. A. Wheeler and the rest of the company of theoreticians in physics have returned to pure science. Many of these men continue as consultants to the atomic energy project, and some are being supported in their own work by AEC grants, but the AEC is not their principal interest

It would be a gross oversimplification to attribute their departure simply to the irksome security restrictions. They have finished their wartime job, have found work that is more fun, prefer the stimulating intellectual atmosphere of a university to the grim environment of bomb-making. Indeed, considering the superior attractions of the campus climate, it is remarkable, as Oppenheimer points out, that the Atomic Energy Commission has held the interest of as many able scientists as it has. And when all is said and done, AEC money remains the principal support for scientific work in the U.S Science, remarks Oppenheimer, "has fattened off the bomb."

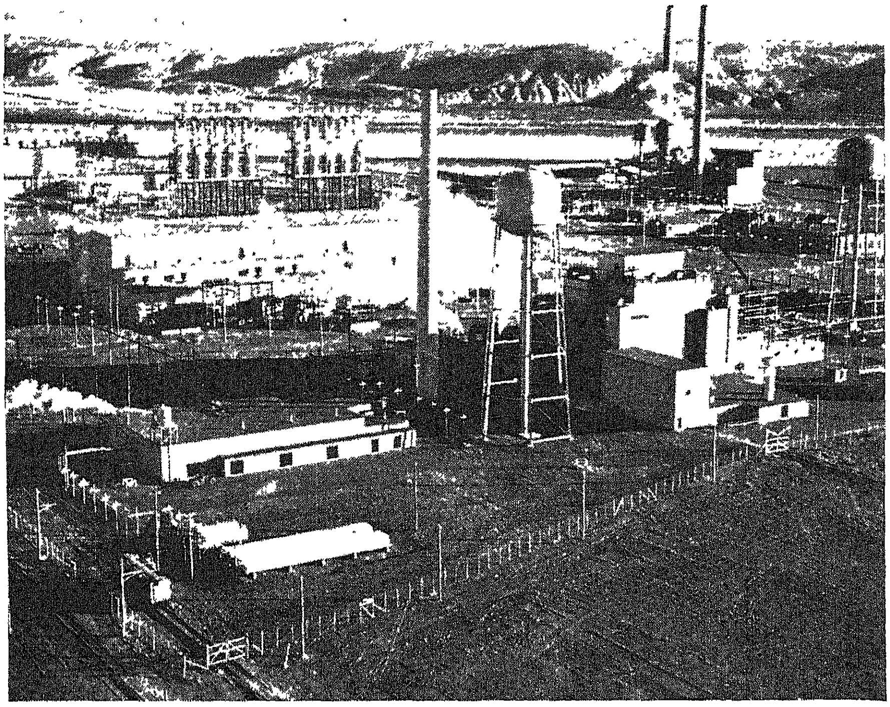
"... if need be to resist..."

Obviously the continuance of this basis of support is far from desirable. The AEC's peaceable activities—reactor development, subsidies to basic science, training of promising young scientists through its fellowship program—are so closely associated with the bomb that their integrity is in serious jeopardy. Sir Henry Dale, the distinguished physiologist and former president of the Royal Society, recently observed to the British Atomic Scientists Association:

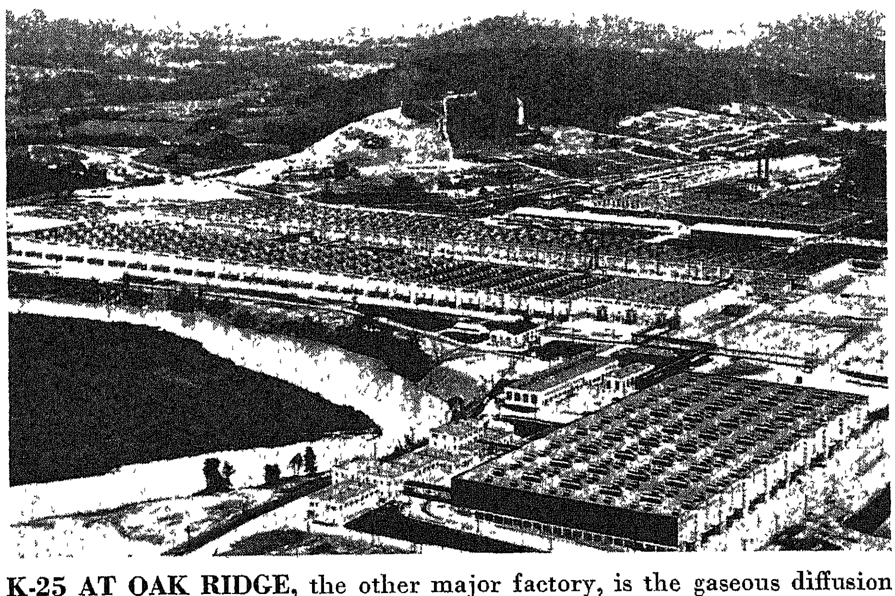
"I fear that it is becoming almost too difficult for some of us even to imagine the freedom of cooperation and the community of interest among all men of science ... which existed for centuries right up to a time within the memories of colleagues of ours who are still alive. ... At present we have been forced very far from that ideal, and the immediate call for our effort may be to challenge, to examine, and if need be to resist any move or threat to push us farther down the slope"

One necessary step to that end in the U.S. appears to be to divorce as much as possible of the Atomic Energy Commission's scientific and educational undertaking from the bomb, and transfer these activities to a national science foundation.

The "atomic age" admittedly has bestowed upon science an opulence of money and equipment such as it has never before known. But the feeling of most scientists is aptly summed up by Oppenheimer: "It would be a healthier world if science were supported for itself."



HANFORD PLANT is one of the two huge production centers of the AEC. Its three piles produce plutonium, which is then extracted from the radioactive uranium slugs by remote-controlled chemical processes carried on behind heavy shielding in long concrete structures known as "canyons."



K-25 AT OAK RIDGE, the other major factory, is the gaseous diffusion plant that separates U-235 from U-238. The U-shaped plant is a mile long, has thousands of diffusion barriers, thousands of miles of pipe and thousands of pumps. It is the world's largest continuous operation under one roof.

SCHIZOPHRENIA AND STRESS

A report on the significant new finding that schizoid patients are unable to vary their production of some hormones to adjust to the varying situations of life

by Hudson Hoagland

NEARLY half of the hospital beds in the United States are occupied by patients suffering from mental illness, and about a third of these patients have a psychosis known as schizophrenia or dementia praecox. This is an all too common and serious form of insanity, affecting nearly one per cent of the population. Brilliant people often develop it and are lost to society.

A quotation from *The Biology of Schizophrenia*, by R. G. Hoskins, describes the behavior of these patients:

"The psychosis represents a bizarre mélange of behavioral normality and abnormality. The core disturbance, the so-called process schizophrenia, is perhaps still best expressed in [the German psychiatrist E.] Kraepelin's definition of the psychosis as 'a peculiar disorganization of the inward coherence of the psychic personality with predominating damage to the affective life and will.' In other words, the patient cannot think straight, feel straight, or will straight His logic limps woefully. He often substitutes phantasy for reasoning and to him argument from analogy is singularly convincing. . . .

"It is these latter peculiarities that led [the German psychiatrist Eugen] Bleuler to ascribe primary importance to 'disorders of the association processes.' Memory and orientation are frequently well preserved. The patient often shows little disturbance of comprehension. Despite frequent appearances to the contrary, he is usually rather well aware of what goes on about him. The fundamental disorder of the thinking processes leads ultimately to such deviations from normality as hallucinations, delusions, poor judgment, incongruity of emotions—often with apparent neutrality or indifference—incoherence in train of thought and displacement of normal volitional responses by automatic or impulsive reactions."

While it is true that everyone probably has a threshold beyond which he breaks down under the batterings of life, it is not true that the mental breakdown need take the form of schizophrenia. Why some people develop a crippling psychosis under very little apparent stress and others do not under great stress is a challenging mystery.

It is an article of faith among most students of the biological sciences that human conduct, from the simplest reflex to the mental achievements of a Shakespeare, depends upon the dynamic functioning of bodily processes and particularly of those of the nervous system, which, of course, includes the brain. Just as physiological events determine mental processes, so we believe that mental processes can determine some physiological events.

In the following discussion we shall not be concerned with the very important techniques of the psychiatrists, who are primarily concerned with the treatment of mental disease at the psychological level. Rather we shall review a specific aspect of the physiology of the adrenal gland which appears to be relevant to understanding the nature of schizophrenia. This work has been carried out during recent years by a group at the Worcester Foundation for Experimental Biology working in collaboration with the research staff of the Worcester State Hospital. The Foundation group has consisted primarily of Gregory Pincus, Harry Freeman, Fred Elmadjian, Louise Romanoff, James Carlo, David Stone and the author. Valuable cooperation has been furnished by Roy G. Hoskins, William Malamud, Eliot Rodnick, Sidney Sands and David Shakow of the Hospital staff. Our studies have been aided by the Office of Naval Research, the U.S. Public Health Service, the Williams Waterman Fund of the Research Corporation, the G. D. Searle Company, the Armour Company, the Schering Corporation and Ciba, Ltd.

The adrenal gland consists of two small organs, located on the top of the kidneys. The gland has an inner region called the medulla and an outer part called the cortex. The adrenal medulla, which secretes the hormone epinephrine, or adrenin, plays no significant part in the phenomena we are about to consider. The adrenal cortex, however, seems to be involved in schizophrenia and perhaps in other mental conditions. During the last two decades some 2,000 papers have appeared dealing with its physiology and the chemistry of its hormones.

Twenty-eight hormonelike substances have been obtained from the adrenal cortex, all belonging to the class of compounds known as steroids. The adrenal-cortex steroids, which are quite different chemically and in their effects in the body from the single hormone of the adrenal medulla, belong to the same chemical family as the sex hormones Some have not as yet been assigned any known physiological role, although the function of others is quite clear. Three hormones, for example, are primarily concerned with converting protein to sugar and storing this potential fuel in the liver. Others regulate the salt and water balance in the body, particularly the balance of sodium and potassium between cells and body fluids which is so essential to the normal functioning of the brain and other tissues.

Unlike the adrenal medulla, which is under direct nerve control, the hormone production and secretion of the adrenal cortex is accelerated by a protein substance released into the bloodstream from the pituitary gland. This adrenocorticotrophic hormone, or ACTH, is discharged from the pituitary by the nervous system, although the exact mechanisms are still obscure. The secretion of ACTH is also partly regulated by the level of adrenal-cortex hormones already in circulation; the higher this level, the less ACTH is released

CONSIDERABLE evidence, especially from animal studies, indicates that adrenal-cortex hormones play a significant role when the organism is under stress. The work of Hans Selye and his collaborators at the University of Montreal (SCIENTIFIC AMERICAN, March 1949) on the so-called "alarm reaction" has been especially illuminating, as have studies from the laboratories of C. N. H. Long of Yale University and Dwight J. Ingle of the Upjohn Company. Animals forced to exercise strenuously, or exposed to extreme cold, surgical injury, or injections of toxic agents, show reversible anatomical and chemical changes in the adrenal cortex. Animals whose pituitaries have been removed do not show these stress-induced changes, and those deprived of the adrenal cortex early in life show marked weakness and lassitude followed by collapse and death. These latter animals have little resistance to stress of any kind.

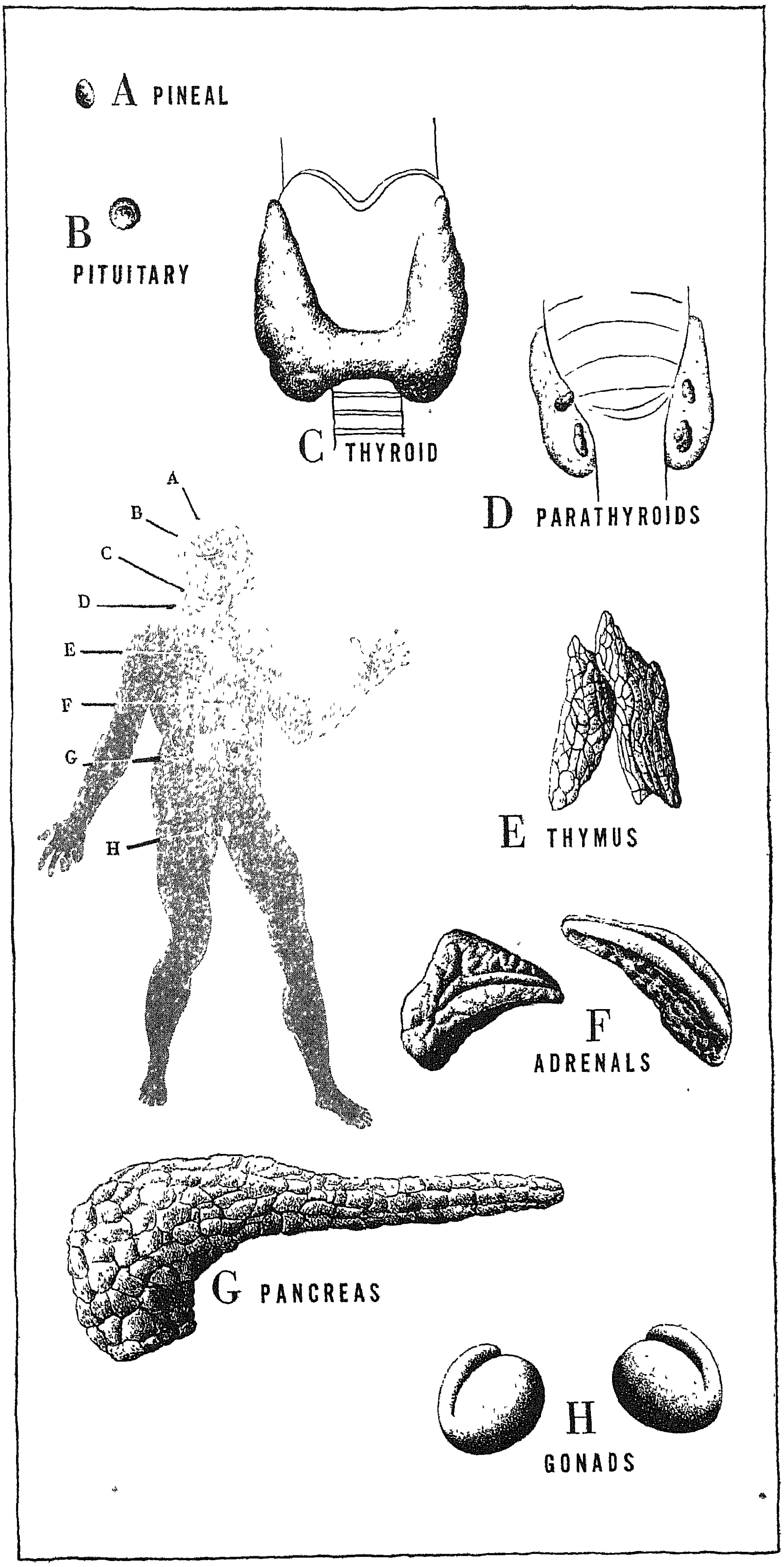
Addison's disease in man has long been known as a destructive disease of the adrenal cortex. It results typically in

progressive lassitude, exhaustion and ultimate death, and psychotic behavior is not uncommon. Animals deprived surgically of their adrenal cortices and Addison's patients can be maintained in a healthy state by administering adrenal-cortex hormones which serve as substitutes for the hormones normally produced by the gland.

During the war Gregory Pincus of the Worcester Foundation and the author studied fatigue in aviators and found that individual differences in resistance to stress were correlated with secretion of hormones from the adrenal cortex. In subsequent studies we found that a wide variety of common workaday stresses produced enhanced activity of this gland, and later we decided to extend our studies to the large group of mental patients who have notably failed to meet the stresses of daily life. We asked ourselves whether these psychotic patients might show inadequacies in this very general stress-response system. Just as the engineer tests the strength of structural materials by stressing them and measuring the strains, it seemed reasonable to stress psychotic patients and normal people by the same standard procedures and compare their adrenal responses.

A number of methods are available for measuring the functioning of the adrenal-cortex hormones in man. Because of their far-reaching effects on metabolic processes, the concentrations of various substances in the blood and urine indicate adrenal activity. Thus, J. F. Dougherty and Abraham White of Yale have shown that certain adrenal steroids produce a drop in the number of white blood cells known as lymphocytes, which make up about 35 per cent of the blood's total white-cell count. They do this by converting some of the protein of lymphoid tissue to sugar, which is then stored as fuel in the liver; as a result of this protein breakdown an end product, uric acid, appears in the urine where its concentration can be determined. Other adrenal steroids whose chemical composition differs only slightly from those concerned with protein and sugar metabolism regulate the excretion of sodium and potassium, so that changes of concentration of these salts in the urine are also useful indexes of the relative amounts of circulating hormones.

Another method of measuring adrenal-cortex activity depends on the fact that the "true" adrenal steroids, in contrast to the steroidal sex hormones, have reducing properties, that is, they can transfer hydrogen atoms to other substances. The total amount of reducing lipids, which are fats and fatlike substances, in sugar-free urine consists mainly of certain adrenal steroids. During metabolism many of these substances, but by no means all, are converted into 17-ketosteroids (*see drawing on page 46*) The 17-ketoster-



THE ENDOCRINE GLANDS all secrete their hormones into the common pool of the blood and the lymph. They are thus able to work delicately orchestrated effects on one another. One such connection, which is discussed in this article, is the stimulation of the adrenal cortex by a pituitary hormone.

oids and reducing lipids may be analyzed in as little as an hour's accumulation of urine. In men 80 to 90 per cent of the 17-ketosteroids are of adrenal origin, the rest are from the testes, in women probably 100 per cent are from the adrenal cortex.

Since 1941 we have been studying the effects of various stresses on adrenal-cortex function among normal men and women and among mental patients. At first the only practical method available for measuring these effects was to determine the concentration of the 17-ketosteroids in the urine. During the past three years, however, we have used in addition lymphocyte counts and changes in urinary sodium, potassium, uric acid and the reducing lipids. Our various studies have involved approximately 200 normal men and women and 100 mental patients, for the most part chronic male schizophrenics.

In our experiments we have used such clearly physiological stresses as exposure to heat or cold and the ingestion of large doses of sugar. All these stresses increase the activity of the adrenal cortex in normal people. We have measured adrenal function before and after the stress and fatigue resulting from prolonged operation of a pursuit meter, a flight-simulating device that has airplane-type controls and is used to test coordinating ability. We have studied activity before, during and after 152 training flights of 16 Army instructor pilots; similar tests were made of 56 flights of seven civilian test pilots. On the purely psychological side, we have also recorded adrenal-cortex function during interviews, during especially designed frustration tests, and during examinations given to college students in regular courses. All of these tests, with the exception of the last one and the actual airplane flights, have been administered both to schizophrenic patients and to normal control groups.

Among normal individuals we find that, within limits, the greater the stress the greater the hormonal output, and we have been able to correlate measurements of the degree of fatigue in the pursuit-meter test with adrenal-cortex secretions. Patients suffering from psychoneuroses (which for the purposes of this discussion may be regarded as less severe forms of mental breakdown) generally exhibited adrenal responses similar to those of normal persons, although often in somewhat exaggerated form

The schizophrenic group showed a striking inability to respond to these tests with enhanced steroid output as measured by our blood and urinary indexes, despite the fact that their normal steroid secretion, as measured after 24 hours of rest, was little different from that of the general population. A schizophrenic does not have an underproductive adrenal cortex, as does the sufferer from Addison's disease, but the organ is generally unresponsive to stress and cannot change its activity with changing situational demands.

One might think that the unresponsiveness was due to lack of interest in the tests and an other-worldly detachment from the experimental procedure, but this notion does not account for the facts. Both patients and normal controls were exposed to heat or cold at the same time and both groups sweated or shivered alike. The controls showed enhanced adrenal activity and the patients did not Moreover, the purely internal stress of assimilating large amounts of sugar administered in our sugar-tolerance tests revealed significant differences in the adrenal-cortex responses between patient and control groups. In psychological tests, including performance on the pursuit meter, the patients were cooperative and their interest in the situation seemed to be as great or greater than that of the control subjects.

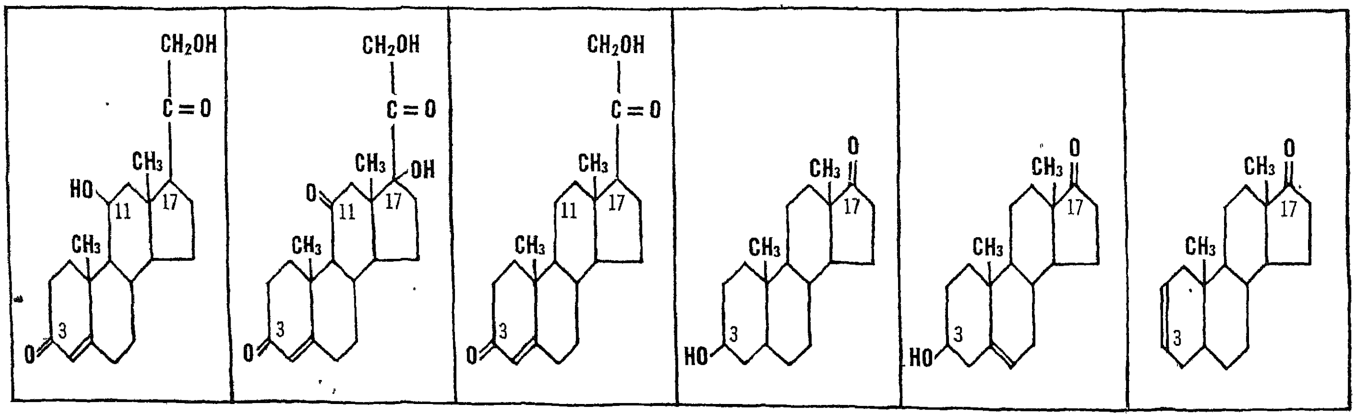
The basis of response failures among the patients was next investigated. Perhaps their adrenal-cortex secretions were normal but their body tissues could not react to the hormones. This possibility was excluded by injecting patients and controls with standard quantities of cortical extract. Both groups showed the same reactivity to the injected hormones.

The failure must then reside either in the inability of the brain to excite the pituitary to discharge its ACTH, or in the failure of the ACTH to stimulate the adrenal cortex. To investigate these alternatives, we injected patients and controls with 25-milligram doses of ACTH and tested our six blood and urinary indexes before injection and at several standard intervals of time afterwards. The results were striking. The ACTH produced vigorous responses in all the controls, but the patients, for the most part, showed little or no response. It was therefore reasonable to believe that the patients' stress failures resulted from the inability of ACTH from their own pituitaries to excite their adrenals.

WE next selected a group of schizophrenic patients who failed completely to react to 25 milligrams of ACTH and injected them with 75 to 100 milligrams. These extra-large doses produced some response To assure ourselves that smaller doses had not failed because of possible inadequacies of the hospital diet, we fed a group of nonresponsive patients for two weeks on an ample protein and vitamin diet and again injected them with 25 milligrams of ACTH. But they were still as unresponsive as before.

The statement that schizophrenic patients do not give adrenal-cortex responses to stress or to ACTH is based on statistical group comparisons. While the correlation between steroid secretion and degree of schizophrenic illness is not perfect, the stress response separates patients from normal persons with a statistical sharpness superior to that of any other physiological criterion of which we are aware.

What then do these findings mean in terms of schizophrenia? They certainly do not imply that adrenal stress-response failure is the one and only "cause" of the psychosis, although it is probably one of the important factors involved. A psy-



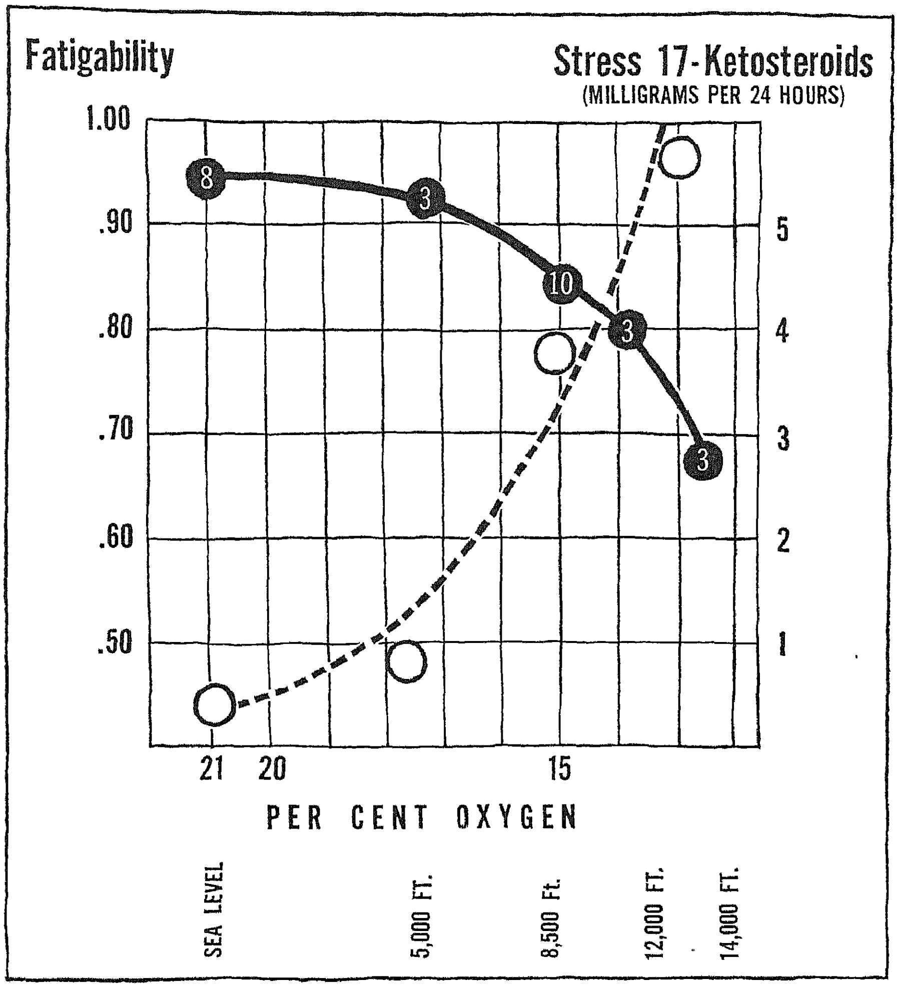
STEROIDS have similar molecular structure. The first three above are the adrenal hormones corticosterone, 17-hydroxy 11-dehydro corticosterone and desoxycorticosterone. The remainder are 17-ketosteroids, named for the keto group at the number 17 position on their molecule. These are breakdown products of adrenal hormones.

chosis is primarily a failure in interpersonal relations determined by a breakdown of higher mental processes which, in turn, depend upon the dynamic patterning and conduction of impulses in billions of nerve pathways in the brain. One of the most conspicuous indexes of stress failure among schizophrenic patients is provided by adrenal regulators of salt balance, and our data on potassium secretion have been particularly consistent in separating patients from controls. Potassium is of great importance in the generation and propagation of nerve messages which are waves of electrical action and constitute the physical basis for thought processes and behavior. Work from our laboratory has shown that the content of potassium in rat brain is altered following stress and that the adrenal cortex regulates brain potassium. Furthermore, neurophysiologists have demonstrated that important electrical properties of nerve depend on its potassium content Such evidence indicates that faulty potassium metabolism in the face of the repeated stresses of daily life may be an important factor in the development of a psychosis.

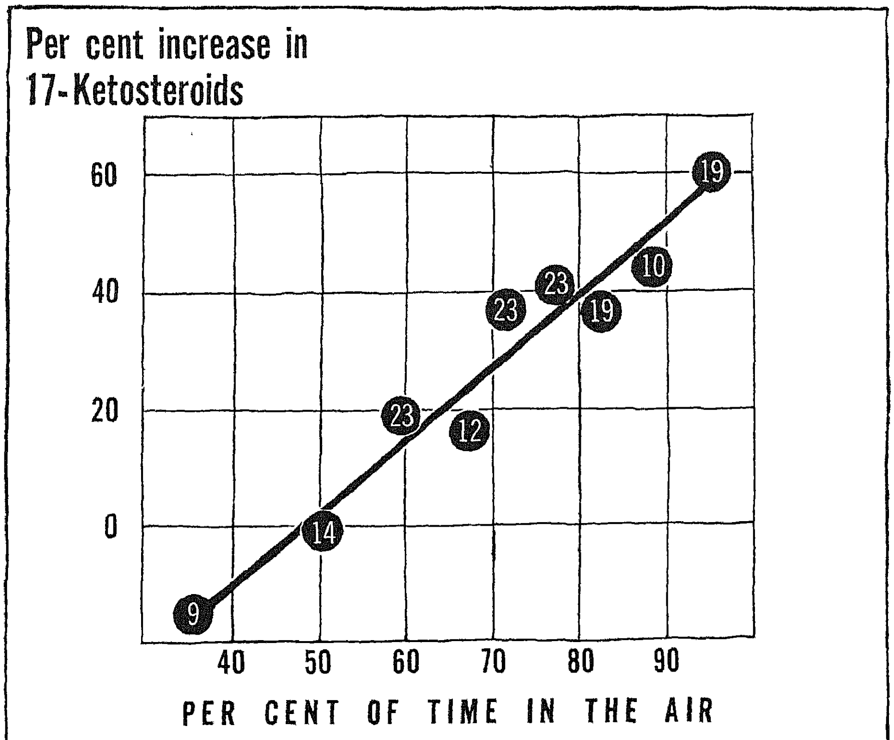
It may be that chemical deficiencies of the kind we have been discussing, perhaps genetically determined, make some persons more vulnerable than others to the stresses of living. They may never become psychotic, especially if their lives present few problems, but under more severe environmental and personalized stresses their physiological defects may result in brain malfunction with consequent psychotic disturbances. This hypothesis warrants further investigation

Our studies to date have not been concerned with treatment but rather with the analysis of basic mechanisms. The schizophrenic is not deficient in over-all output of adrenal-cortex hormones. In the absence of the pituitary the hormones are released from the cortex in man and animals at a constant rate. It is the patients' stress responses that are defective. In a normal person these responses involve *varying* hormone output to meet fluctuating demands It is possible that current shock therapies, which are violent stresses, may activate sluggish pituitary-adrenal systems. Very large doses of ACTH do excite the patients' adrenals. We are therefore starting to investigate the therapeutic value of repeated large doses of ACTH. While our work to date offers no immediate promise of cures, the discovery of a basic physicochemical defect in most schizophrenic patients presents grounds for believing that future research may yield results of practical therapeutic value.

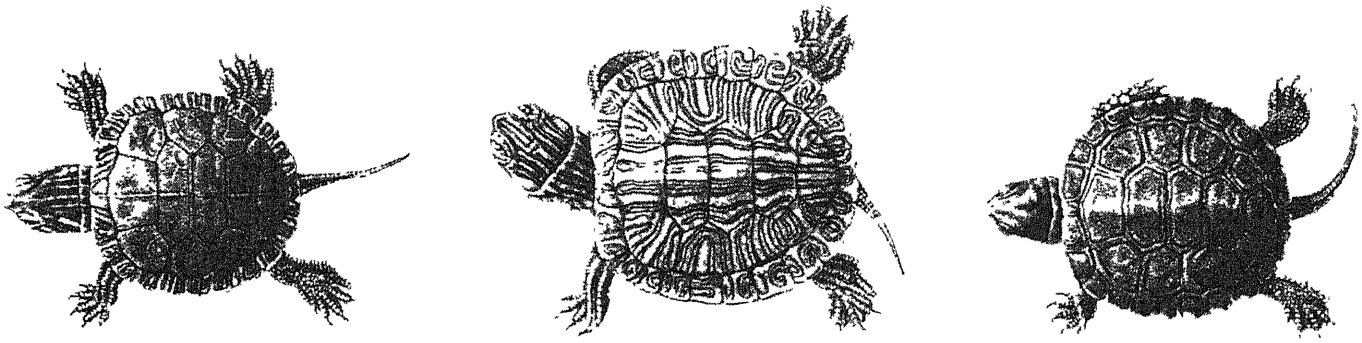
Hudson Hoagland is a physiologist with the Worcester Foundation for Experimental Biology, Tufts College Medical School and the Worcester State Hospital.



PURSUIT METER showed that, as men received less oxygen, fatigability increased and ketosteroid output decreased. Figures on heavy line indicate number of tests. Dotted line shows increase in ketosteroids above resting level.



ACTUAL FLYING also produced increase in 17-ketosteroids. Number of flights is indicated in circles. This showed that 17-ketosteroids are normal metabolic result of stress. Schizophrenics do not show such responses.



YOUNG TURTLES were beautifully drawn in Agassiz' *Contributions to the Natural History of the United States*. At the left is *Chrysemys oregonensis*. In center is *Trachemys elegans*. At right is *Actinemys marmorata*.

Louis Agassiz

The great Swiss biologist had two careers. The second, which began with his arrival in the U. S., did much to awaken the American people to the importance of science

by Alfred Sherwood Romer

An elderly gentleman of my acquaintance remembers well, from his Philadelphia childhood, a December day in 1873. Gloom descended with the arrival of the morning paper at the family breakfast table. It continued as he walked abroad with his father, who conversed with friends in the streets in subdued and solemn tones. To the small boy it seemed as if a national calamity had occurred. In a sense it had, for news had arrived that the great Louis Agassiz was dead.

Among the general public the death of even the most eminent scientist usually causes no more than a brief ripple of interest and regret. To the people of his day Louis Agassiz was not just a scientist—he was the embodiment of science itself. To this small boy (and perhaps to his elders as well) it seemed as if, with the passing of Agassiz, science itself lay dead.

During his quarter-century residence in this country at Harvard University, the Swiss-born biologist became one of the truly great popularizers of science. In his will he described himself simply as "Louis Agassiz, teacher." It was as a teacher rather than as a research man that he was known to his adopted countrymen—not merely a teacher of prospective scientists and college students but one who, with unbounded enthusiasm and charm, expounded the beauty and wonders of nature to the masses of the country. More than any other man he furthered the widespread respect for science in America, without which the rapid growth of later decades would have been impossible.

Jean Louis Rodolphe Agassiz was born in 1807 in the French-speaking Jura region of Switzerland, the son of a minister of Huguenot descent. Early in life he showed a strong bent for natural history. His growing talents forced his family to the conclusion that, despite the financial circumstances of a ministerial household, Louis should have a university education. At the University of Zurich he soon exhibited that combination of a brilliant mind with unbounded vitality and personal attractiveness that made him an outstanding figure throughout his career. It became obvious that he deserved a broader training than that available at the little Swiss institution. Further studies took him to Heidelberg and then to the newly founded Bavarian university at Munich. Here Agassiz became a member, then the leader, of a brilliant group of students and young instructors in science. His scientific advance was rapid; even before obtaining his doctorate at the age of 23, he had written an important monograph on the fishes of Brazil.

When his schooling began, it was assumed that young Agassiz would become a medical man, a country practitioner with scientific interests as an avocation. Following his graduation in 1830 he did indeed return home for some months and made a half-hearted attempt to practice medicine Then his eyes turned to Paris, in those days the greatest center of biological research in the world. The scientific leader of the French capital was Baron Cuvier, founder of the sciences of comparative anatomy and vertebrate paleontology, a potent figure in government circles as well as the greatest zoologist of his time. It was inevitable that Agassiz should go to Paris. Cuvier was a cold, austere, remote figure to most of his fellow scientists; to everyone's surprise, and to the gratification of Agassiz, he opened his heart and his laboratories to the attractive and talented young Swiss. With the support of the master, Paris seemed but one more upward step in Agassiz' career.

But his progress was soon checked. Within the year Cuvier died of cholera and Agassiz lost his chance of a Paris post. A few months later he was offered and accepted a very modest professorship at the Lyceum of Neuchâtel in his native Jura, a position he held for more than a dozen years. Soon after returning to Switzerland he married Cecilia Braun, the sister of a German student friend; she bore him two daughters and a son, Alexander, who later became a famous oceanographer.

Why Agassiz elected to accept the Neuchâtel position is a bit of a puzzle;

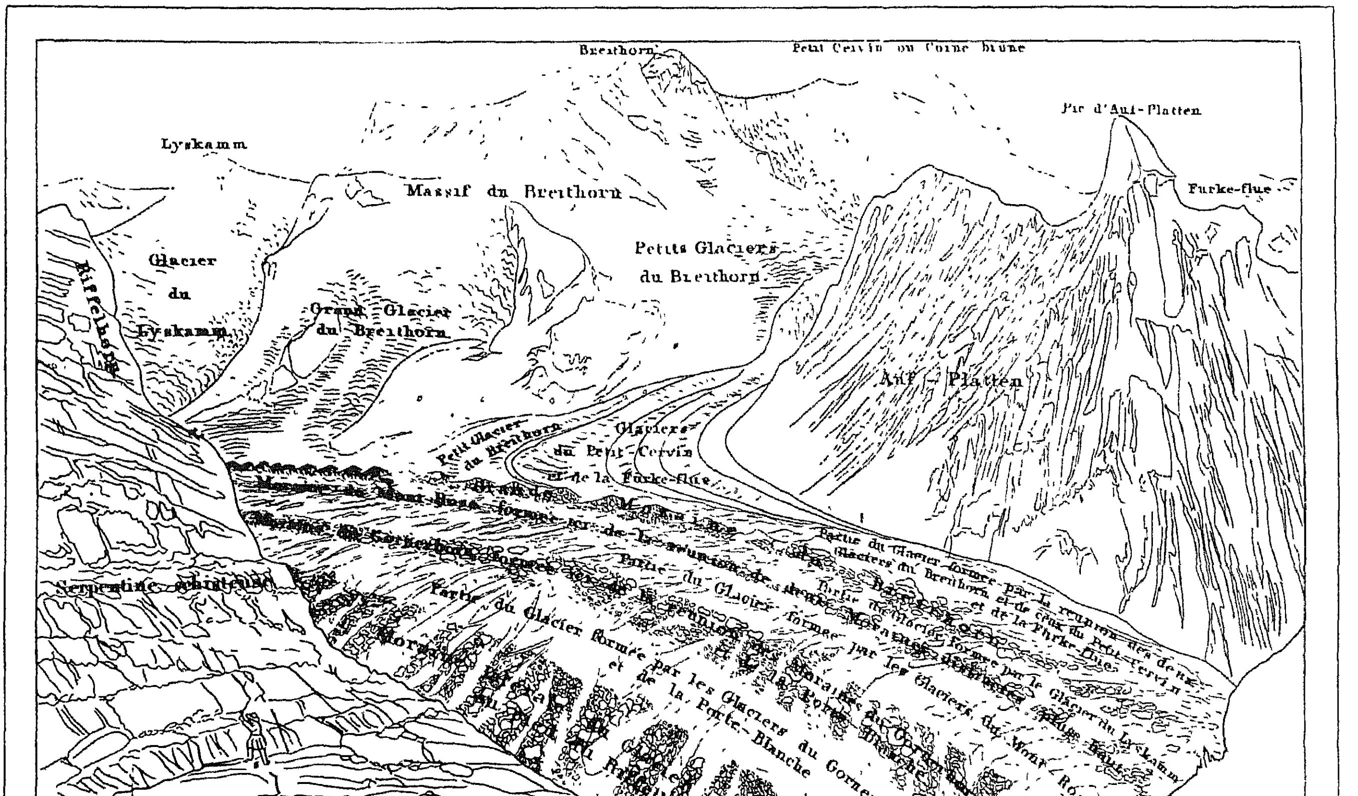
at the time, his friends must have considered the move a disastrous setback. Neuchâtel was a small town, the Lyceum undistinguished, the salary small. It was as if the white-haired boy of one of today's great university departments were to forego a promising career to accept a job in a minor junior college or high school.

But the youngster who went to Neuchâtel was no ordinary man, any institution he entered could not but become important. While he was there, Neuchâtel was a major scientific center. Although his post offered little incentive or financial aid for scientific investigation, Agassiz completed about 200 publications during this period, including 20 stout books with some 2,000 excellent illustrative plates. Today substantial support from research foundations frequently enables a brilliant man to gather around him a large team of scientists. Agassiz built himself a major research institute without such backing. Artists and assistants were always at hand. Funds were low, but at the worst there was sleeping space in the Agassiz home, food at his table. Preparation of the countless plates for his works was difficult: Agassiz sponsored his own lithographing firm. No medium for publication was available Agassiz became his own publisher.

AGASSIZ made his two most important contributions to scientific research during the Neuchâtel period The first was his work on fossil fishes. Cuvier had devoted much time to the study of the more advanced vertebrate classes, but little had been done on the remains of fishes, although they are as numerous and as diversified in nature as all the rest of the backboned animals put together. From his student days Agassiz had determined to conquer this difficult field His work, published in parts over a dozen years, finally totaled five volumes with hundreds of magnificent plates. It gained for him a high place in the European scientific world by the time he was 30, and Agassiz' *Poissons Fossiles* is still the classic on the subject.

His work on glacial geology was perhaps even more important. Switzerland is one of the few places outside the polar regions where glaciers are prominent features. Noting the presence of "erratic" boulders in the Rhône Valley, two fellow Swiss geologists had suggested that the local glaciers, now confined to the high mountains, had once spread more widely over the plain below. Agassiz was skeptical of their conclusions and went to see for himself. He was soon convinced, but his alert mind swept him on at once to hypotheses far wider than their limited conclusions. He had seen phenomena comparable to those of the Rhône Valley elsewhere in Switzerland, and his readings in the field of travel brought to his mind similar conditions reported from many other regions From this evidence he deduced that in relatively recent geological time there was a great ice age when large areas of the world were covered by continental glaciers. Advanced against the strong opposition of most of the senior, conservative geologists of the day, the theory of this young upstart triumphed. It is now one of the accepted tenets of geology. To test the theory Agassiz and his colleagues spent a number of summers observing present-day glaciers. For several seasons their headquarters was the "Hotel des Neuchâtelois," a rude shelter beneath a boulder on the moraine of the Aar Glacier.

Agassiz' years at Neuchâtel were years of much scientific achievement, but his position there became shaky indeed. He was a magnificent optimist, without a trace of practical business sense. His affairs were run on the most slender of shoestrings, and relatives and friends



GLACIERS were one of Agassiz' earliest interests. This illustration, showing the Zermatt Glacier of Switzerland, appeared in Agassiz' *Etudes sur les Glaciers*. This was published in 1840 during Agassiz' stay at Neuchâtel.

were repeatedly rescuing him from financial difficulties. By 1845 it was clear that the Neuchâtel days were nearing an end His resources and those of his local supporters were exhausted, and debts from his scientific enterprises were piling up. His lithographic firm failed and two of his most valued assistants left him His wife, ill and discouraged, departed for her family home in Germany.

As usual Agassiz' optimism was ultimately rewarded By a curious quirk of political history, Swiss Neuchâtel was then a part of the domains of the King of Prussia, who gave the scientist a grant for a scientific visit to America. The amount of money involved was not great, but soon afterward Agassiz was invited to deliver a well-paid series of popular lectures on biology at the Lowell Institute in Boston. Agassiz was enthusiastic. He had always wanted to travel, but no opportunity had previously presented itself. During the following winter he wound up his affairs at Neuchâtel in preparation for the trip—in theory he was merely going on a leave of absence. The general feeling was that this was the end of his career in Switzerland—which proved to be true.

Agassiz packed two full scientific careers into his 65 years. When he left Europe in the summer of 1846 he was just under 40 years old and had already accomplished as much in research and received as great distinction as has many a notable scientist by the time he retires. In America, during the quarter-century remaining to him, he was to lead another equally notable though different life. In Europe Agassiz had been almost entirely a research worker. In America his fame rests not so much on his investigations as on his promotion of science.

It was soon obvious that Agassiz and America were made for each other. His Lowell lectures in Boston were an instant success. Large audiences found his enthusiasm infectious, his personality charming. The public lectures had to be repeated, and during the months that followed he lectured with great popular acclaim in major East Coast cities. Agassiz was eager to teach; America was eager to be taught. Here was a people who, like himself, dreamed great dreams and energetically set about turning them into realities; a people who might aid him in making his own great dreams come true. He was warmly welcomed in America by scientists and laymen alike, while Swiss politics were dubious and his personal prospects none too sure. As a result, he readily accepted an offer of a professorship at Harvard, and Cambridge became his second home. Later he received many other offers from American and European universities, but he refused them all.

When he first settled in Cambridge, his house overflowed with collections and livestock (a bear was a basement resident for a period) and also with a swarm of associates from Switzerland. It is said that at one time no fewer than 23 of them enjoyed the hospitality of this new Hotel des Neuchâtelois.

Soon after his arrival in America, Agassiz' first wife died in Germany and in 1850 the ties to his new home were strengthened by his marriage to Elizabeth Cary. She was an ideal wife—secretary, collaborator, counsellor and a second mother to his orphaned children. Agassiz remained as improvident as ever in America, spending all available money on scientific ventures. To bolster the family finances Mrs. Agassiz, with the aid of the children and the professor himself, established a flourishing girls' school.

The professor was not a sessile organism. He could never stay put, and traveled far and wide on lecture tours and scientific expeditions. His most notable expedition was a trip to Brazil in 1865-66. It lasted 16 months, 10 being spent on the Amazon—a river of intense interest to Agassiz, for its fish had been the subject of his first research monograph. For once in his life Agassiz had no financial worries. A wealthy Boston admirer supported the trip liberally, and the staff included some 15 paid and volunteer assistants

Agassiz continued his research. Indeed, he entered new fields, particularly marine zoology (unfamiliar territory to him during his earlier life in inland Switzerland). His numerous American publications include such substantial works as the four-volume *Contributions to the Natural History of the United States* Nevertheless, if his work be viewed objectively, one must admit that the research of his later years does not measure up in originality and lasting value to that of his European period

America had already produced a number of scientists of distinction, but most of them were little recognized and uninfluential. In the colleges and universities of the country science was for the most part frowned upon as a noxious weed in the prim and classical academic garden. At Harvard and Yale the establishment of separate scientific schools—Lawrence and Sheffield respectively—proved the means of entering the hitherto forbidden gates. Agassiz was the first appointee to the Lawrence Scientific School, in fact, his presence and availability seem to have been the stimulus that brought the initial offer of scientific support from Abbot Lawrence. Agassiz spent the rest of his life furthering the growth of this school which with Sheffield had a great effect on the development of university scientific teaching. In later decades science teaching has been quite properly merged with the general academic curriculum.

Although odd cabinets filled with curiosities and natural-history objects were to be found here and there, almost nothing in the way of natural-history museums existed in the United States at the time of Agassiz' arrival. He became fired with the ambition to create in Cambridge a museum comparable to the great institutions of Paris and London, and worked energetically to that end. An opening came in 1859 when an admiring friend willed $50,000 for the endowment of such a museum with the stipulation that it be called (as Agassiz suggested) the Museum of Comparative Zoology, an unwieldy name that it bears to this day. With this initial gift as a lever, Agassiz turned his efforts to raising further funds for the new institution, to amassing collections and to gathering a research staff. Although his ambitious plans were far from fulfilled, Agassiz could say with justification, shortly before he died, that it already compared favorably with major European institutions.

Agassiz' unique contribution, however, lay in his own teaching of students and the public. No amount of instruction can make a teacher out of a man who lacks an enthusiasm for his subject and the ability to infect his audiences with equal enthusiasm. Agassiz had these characteristics in overflowing measure. He had to teach, and his listeners always responded. He could deal equally well with the vast crowds of his lecture tours or a single advanced student in the laboratory. He loved his subject so much that, in default of a larger audience, he would lecture on natural history to a cabbie driving him to his hotel or to a fisherman in a rowboat.

TENS of thousands of young students today are introduced to the name of Agassiz by a quotation on their rulers. "Study nature, not books." Although the professor probably never uttered these exact words, they do express the essence of his teaching. For the advanced student who came to work with him, acute observation of nature replaced the dull pedantry and reliance upon written authority which had persisted in universities from the Middle Ages to the earlier 19th century. Students responded to this sort of treatment, budding zoologists flocked to him and left Cambridge to spread the gospel of Agassiz' teachings. Most biologists in the country today are to some extent the scientific descendants of Agassiz although, with the constant expansion of the field, a large number are working in areas that were undreamed of in his day. A list of his students would include many men who dominated American zoology in later decades of the century, and others who became prominent in fields as far apart as geology and psychology.

In Switzerland Agassiz' teaching had been confined to academy students and home-town friends. In America he dis-

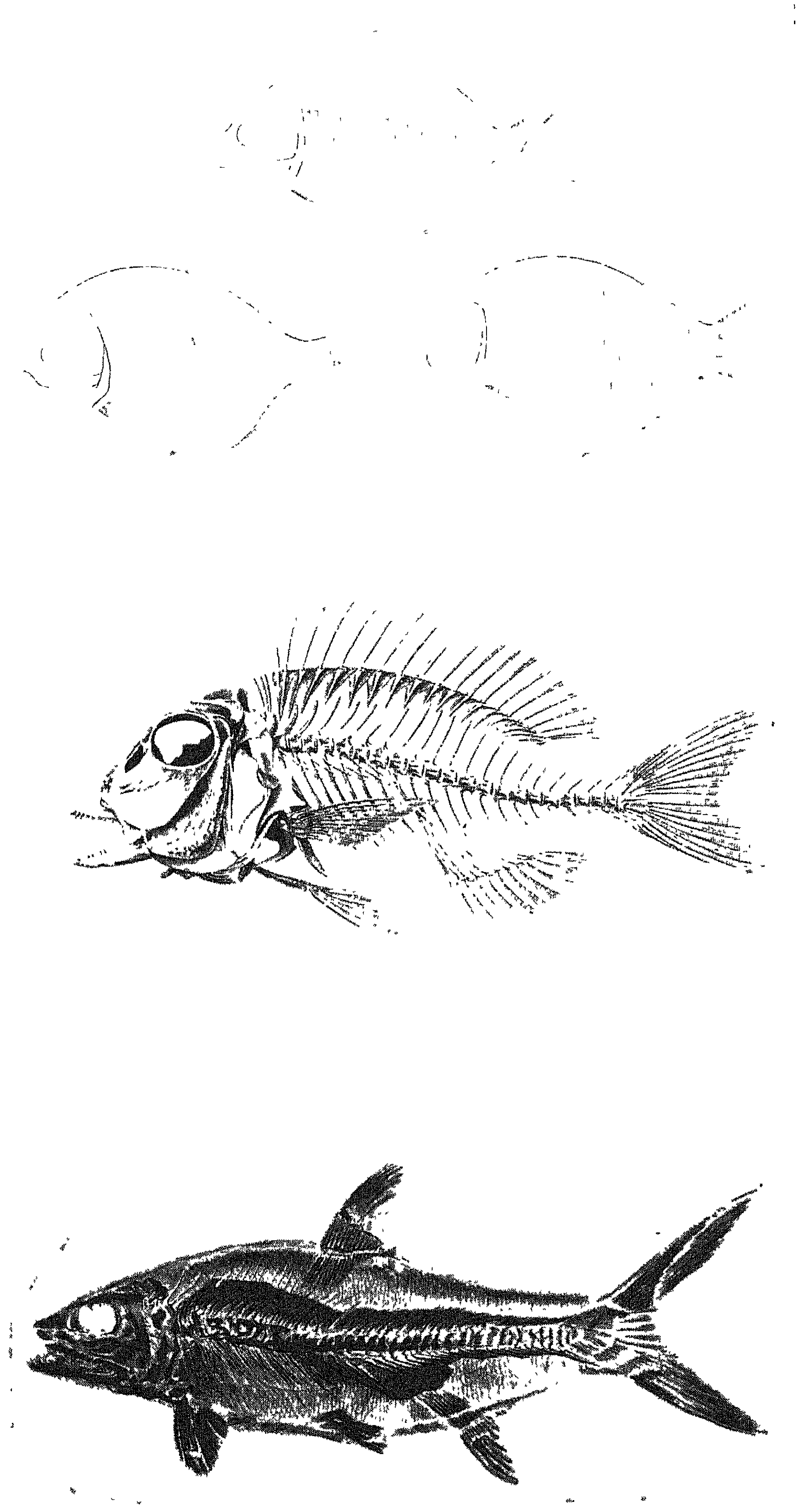
covered, and delighted in, his ability to capture and hold great audiences, learned and unlearned alike In the 19th century attending public lectures was the greatest indoor pastime, and Agassiz enjoyed and was inspired by any type of attentive group. Furthermore, he needed money, not for himself, but for his scientific work and for the support of his museum. Here were hosts of people willing to listen and learn and, moreover, willing to pay for the privilege. And so, time after time, Agassiz toured the country from the Great Lakes to the Gulf of Mexico, from the East Coast to the growing prairie towns. His audiences never tired of him. His command of English never became perfect He always had a strong accent and frequently he had to pause and grope for the proper word. These imperfections were more than balanced by his clarity, simplicity and enthusiasm, and only endeared him further to the public He fostered a popular interest in research and its support, without which American science would have remained impotent.

Agassiz' written works are evidence of his importance as a research worker. The historian can readily trace the effects of his teaching as it has been transmitted through successive generations of his scientific descendants. But it is extremely difficult for us to realize the personal magnetism that helped so much to make his teaching effective. William James, the philosopher, gives part of the picture: "He was of so commanding a presence, so curious and inquiring, so responsive and expressive, and so generous of himself and of his own, that everyone said of him. 'Here is no musty savant, but a man, a great man . . .' "

Alice Bache Gould, one of Agassiz' biographers, has strung together some of the phrases that his contemporaries used to describe him. "His genial countenance; his great face beaming with pleasure, the eyes whose sunshine runs before the lips, a firm benignity of face, and winning ways, his phrases all the more taking for the broken English, an inexhaustible buoyancy and huge good fellowship; robust and dominating; cheerful, kindly, engaging, frank, irresistible; ingenuous, glad, great-hearted and bewitching, the jovial giant, the acknowledged master, a man to be thankful for."

Truly a man for science to be thankful for. American science has traveled far since his day. Its progress would have been much slower, its triumphs less great, without the example set by Agassiz and the public support and respect engendered by his teaching.

Alfred Sherwood Romer is director of the Museum of Comparative Zoology at Harvard University.



FOSSIL FISHES were another of Agassiz' interests during his European career. After working with the great Baron Cuvier, who founded the science of vertebrate paleontology, Agassiz took up the relatively little-studied fishes. The result was his classic work called *Recherches sur les Poissons Fossiles.*

The Physiology of Whales

As man has learned to dive deeper and deeper, he has taken an increasing interest in the remarkable diving abilities of the great oceangoing mammals

by Cecil K. Drinker

AMONG the miscellany of creatures that inhabit the earth, whales possess a peculiar interest. Although they are air-breathing mammals, their highly specialized physiology permits them to remain under water for prolonged periods of time. Their great size is well known. Many people think that some reptiles of the geologic past were bigger, but this is not so. As far as we know, the largest animal that has ever existed is the blue whale, or Sibbald's rorqual.

The illustration on the opposite page compares the sizes of a few animals. Among the creatures shown are the blue whale; Jumbo, the largest known elephant; and a specimen of *Brachiosaurus*, one of the largest dinosaurs. *Brachiosaurus* had a relatively short tail, but the animal may have reached a length of 80 feet and a weight of 50 tons. Blue whales up to 110 feet have been described, and modern methods have made it possible to estimate their weight at more than a ton per foot. So the sea has preserved an animal twice as bulky as *Brachiosaurus*.

A newborn whale is 20 to 30 feet long and apparently suckles for about a year Many structural features of whales suggest that they evolved from a branch of early mammalian carnivores that first lived on land and later took to the sea and fish-eating as an easier way of life. The whalebone whales, of which the blue whale and the fin whale are the largest, are toothless, but they are believed to have descended from some kind of primitive toothed whale. Primitive whales, the archaeocetes, first appeared in the Middle Eocene period some 40 million years ago. Gradually, with the telescoping of the skull and the development of a peculiar whalebone apparatus in the mouth for trapping food particles, this type of whale lost its teeth, learned to live on small crustaceans that the sea provides in vast quantities, and slowly increased in size.

In the Antarctic, where the hunting of blue and fin whales is still very profitable, the water is sometimes colored red by schools of tiny creatures known as "whale feed" or "lobster krill." The whalebone whales swim back and forth through the schools with their mouths open to scoop in the little crustaceans, which are then strained by the whalebone and swallowed. A blue whale is able to consume some 250 gallons of lobster krill at one feeding

As man has learned to dive deeper and deeper, he has developed an increasing interest in the physiological abilities of whales Most of us know that if a diver goes down to 100 feet and works for an hour, he must be brought to the surface slowly to avoid caisson disease, or the "bends." At sea level, where the atmospheric pressure is about 15 pounds per square inch, a man of average size has about 1,000 cubic centimeters, or nearly a quart, of nitrogen dissolved in his body fluids and tissues. The gas has no physiological value, but it nonetheless dissolves into the blood which passes through the lungs. At a depth of 100 feet the diver is subjected to a pressure four times that at the surface. A constant supply of air is pumped to him at a pressure corresponding to his depth. He steadily absorbs nitrogen until his body fluids and tissues contain four times the normal amount of the gas

Now suppose that the diver is brought to the surface in a few minutes. During his stay on the bottom his body has absorbed three extra quarts of nitrogen, which must be released and breathed out as it was taken in—through the lungs. The dissolved gas must travel in the blood to reach the lungs, so it diffuses rapidly into the capillaries. In these tiny vessels it may attain such a high degree of concentration that it comes out of solution and forms bubbles, which may readily be seen under the microscope. These cause air embolisms, *i.e.*, they block the flow of blood in the capillaries. They may cause pain in areas poorly supplied by capillaries, such as the joints, and they may lodge in the heart, the lungs or the brain to cause sudden death

Various methods of preventing the bends have been proposed or tried. The condition could be avoided if the diver breathed pure oxygen before diving, and continued to breathe it during his dive. The trouble with this stratagem is that at a pressure of four atmospheres pure oxygen is a dangerous poison if breathed for more than brief periods. It irritates the respiratory passages, and after a time causes serious convulsions. To solve this problem helium may be mixed with oxygen, just as nitrogen is mixed with oxygen in the air. Since helium is much less soluble than nitrogen in the body, particularly in fatty tissues, it is breathed in and out by the diver and is not stored in solution, ready to burst out when the pressure is lowered.

The diver normally avoids the bends by a simpler method. He comes to the surface by slow stages and gradually breathes out excess nitrogen. If his ascent has been too fast and he collapses on the deck of the mother ship, his companions put on his helmet, throw him over the side, and lower him to a depth where the pressure will again cause the bubbles of nitrogen to dissolve. In the best diving operations the mother ship

is equipped with a pressure chamber. When the diver is brought to the surface, he is locked in the chamber and the pressure is raised until he is safe and comfortable. The pressure then may be gradually lowered.

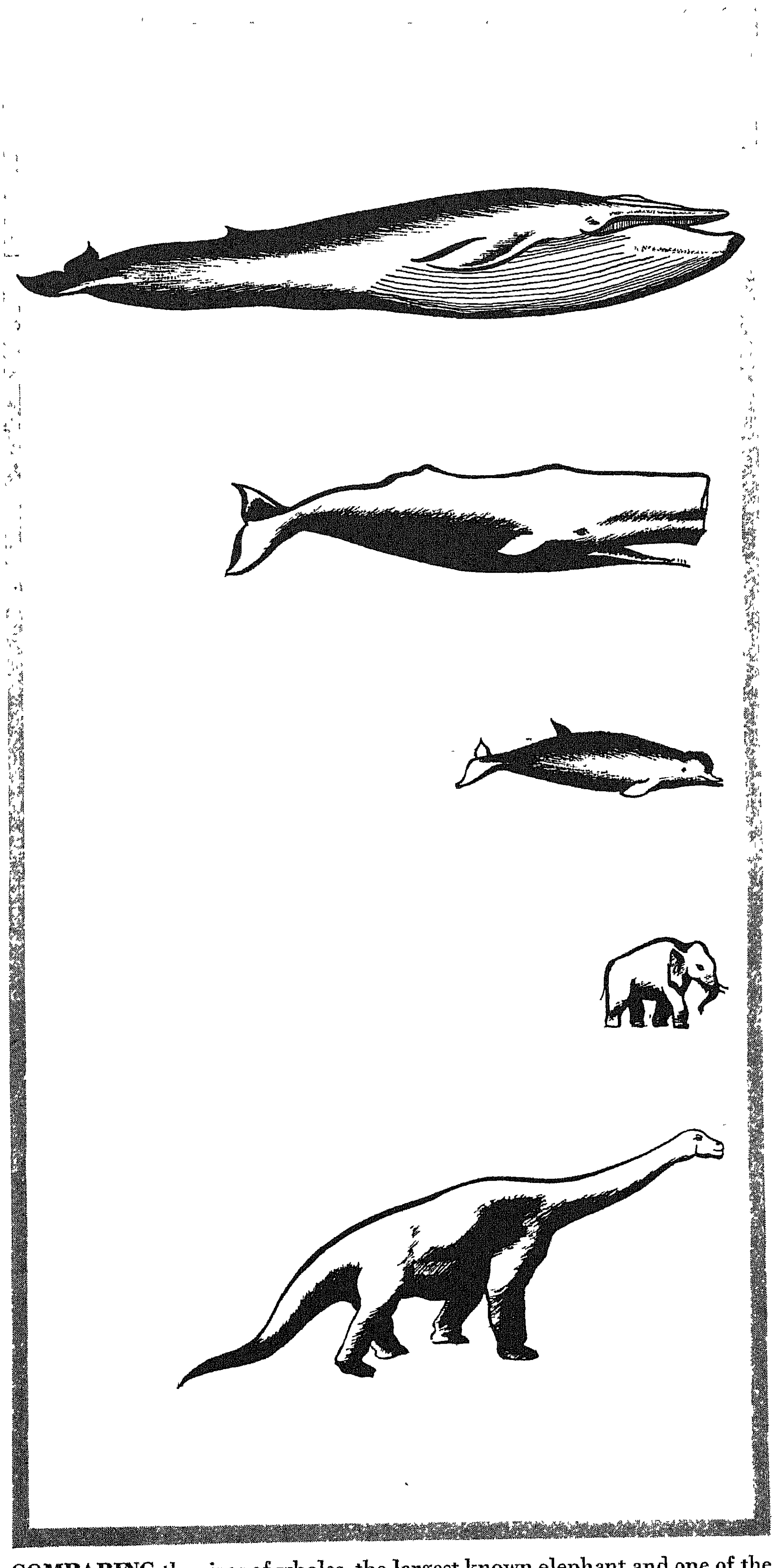
WITHOUT a continuous supply of air or oxygen man cannot stay under water for more than two to five minutes. Although breathing oxygen before the dive will extend this time, the fact remains that centuries of diving have not improved man's ability to stay submerged. Diving animals of all kinds are much better at it. Laurence Irving of Swarthmore College has assembled the data in the table on page 54 It is obvious that in general the bigger the animal, the longer it can stay under water. Irving calls attention to exceptions. the muskrat, the beaver and the gray seal, which are quite different in size but rather evenly matched in their ability to remain submerged.

The whales, of course, hold all diving endurance records. The blue whale can submerge for 50 minutes, the sperm whale, for 60 to 75 minutes The bottle-nosed whale—smaller, but a toothed bottom feeder—can stay down for two hours.

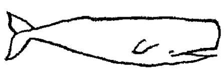
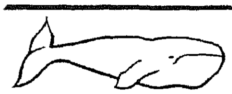
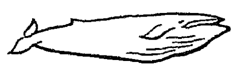
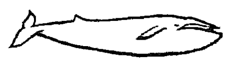
The depth that diving animals can attain also is significant. Men wearing diving suits and breathing helium and oxygen have withstood the pressure of 550 feet; in closed spheres, of course, they have gone deeper. Whales, on the other hand, can dive many hundreds of feet without such devices.

In 1933 the British Colonial Office issued a report by Alec H. Laurie that summarizes our scanty information about the depth and duration of their dives. Little is known about the usual diving period of blue whales. When they are chased they usually hide beneath the surface for periods of 10 minutes or so. A harpooned blue whale may submerge for half an hour. It has been said that blue whales that have been harpooned but not vitally injured can dive almost vertically to 1,800 feet. This estimate appears to be based on the length of harpoon line paid out, which is a poor measure of a whale's diving ability. A harpooned whale does dive almost vertically at first, and the line may seem to remain vertical afterward As the animal attempts to escape, however, the line may form a huge loop with the whale in front and the boat behind.

The depths to which whales normally dive may be inferred from the habits of the creatures on which they feed. In the Antarctic large schools of whale food reach depths of 650 feet, although the greatest number of these organisms are found at about half that depth. One may assume that in normal feeding the blue whale submerges from 100 to 300 feet and stays down 10 or even 20 minutes.



COMPARING the sizes of whales, the largest known elephant and one of the largest known dinosaurs shows that the whale is the largest animal ever to inhabit the earth. At the top is the blue whale. Below it is the sperm whale. Third is bottle-nosed whale. Fourth is the biggest elephant. At bottom is *Brachiosaurus*, a short-tailed but big-bodied dinosaur of the Upper Jurassic.

	Platypus	10 minutes
	Sea elephant	6 minutes 48 seconds
	Harbor seal	15 minutes
	Gray seal	15 minutes
	Muskrat	12 minutes
	Beaver	15 minutes
	Hippopotamus	50 seconds
	Florida manatee	16 minutes 20 seconds
	Sperm whale	1-1¼ hours
	Bottle-nosed whale	2 hours
	Bowhead whale	1 hour 20 minutes
	Greenland whale	1 hour
	Common rorqual	49 minutes
	Blue whale	50 minutes
	Finback whale	½ hour
	Fin whale	20 minutes
	New Zealand humpbacked whale	Not over ½ hour

DIVING PERIODS of various aquatic mammals, originally compiled by Laurence Irving of Swarthmore College, are listed. The longest period of submergence is achieved by the relatively small bottle-nosed whale, which feeds on octopuses at the bottom. Aside from such exceptions, there is an approximate correlation between the diving ability of mammals and their size.

Sperm whales and bottle-nosed whales feed on octopuses, which live on the bottom, so they undoubtedly go deeper than whalebone whales. In 1931 a dead sperm whale was found entangled in a submarine cable that had broken at a depth of 500 fathoms, or 3,000 feet.

In 1940 P. F. Scholander, working at the University of Oslo, attached recording manometers to harpoon lines and found that fin whales dived to depths of 284 to 1,164 feet after they had been hit. How long they remained at maximum depth could not be ascertained. The whale that made the deepest dive came to the surface and towed the whaleboat for half an hour before it was killed by another shot. Another whale that was only slightly wounded dived to 753 feet, came to the surface and, after four or five spoutings, suddenly died. This seemed rather like a case of the bends, perhaps resulting from the fact that the whale dived deep, remained at depth for most of the period of submergence and finally came to the surface rapidly.

There are two principal questions in whale physiology. How does a whale succeed in remaining under water for prolonged periods, even when doing hard muscular work? And how, in the great majority of cases, does it escape air embolism due to the blocking of small blood vessels by bubbles of nitrogen?

The first question may be approached by considering the breathing mechanism in man. Human breathing is initiated and regulated by the respiratory center, a group of nerve cells in the medulla oblongata at the top of the spinal cord, and by nerve cells and fibers in the walls of the carotid sinus, a dilated channel at the bifurcation of the carotid artery, the principal vessel supplying blood to the brain. The respiratory center is stimulated strongly by the accumulation of carbon dioxide in the blood, the carotid sinus by a decrease in blood oxygen. When a diving bird or a land or sea mammal submerges, breathing stops automatically. In a man, this cessation of breathing cannot last long because he is soon forced to breathe by the stimulus of mounting carbon dioxide. Holding the breath causes carbon dioxide to diffuse into the blood, and within one or two minutes enough accumulates to produce an irresistible impulse to breathe. According to Irving, whales and other diving mammals are much more resistant to this effect.

Whales have another adaptive mechanism. In all animals, when exercise accompanies the cessation of breathing, carbon dioxide accumulates very rapidly as a result of the oxidations responsible for the energy of muscular contraction. Although a steady supply of oxygen is essential to the heart, to the brain and to nerve tissue in general, voluntary muscle can contract when there is very little oxygen in the blood. This is accom-

plished by drawing on a reserve source of energy: the transformation of glycogen, or animal starch, into lactic acid. This muscular contraction without oxygen cannot, however, continue long, and it must be paid for by the intake of more oxygen to restore the glycogen to the muscle cells

The individual organism thus incurs an oxygen debt which is paid by breathing when submergence is finished. Obviously the ability to secure such a loan may serve to permit work during a period of oxygen deprivation, but since the brain and heart have no reserve source of energy and are unable to function without oxygen, some provision must exist to keep them supplied with oxygenated blood.

The brain and heart of the whale apparently escape asphyxia during prolonged submergence because of reflex nervous reactions that occur when breathing movements cease. The flow of blood through the brain increases, due to the dilatation of cerebral vessels, and circulation through the muscles decreases. Increased carbon dioxide and decreased oxygen in the blood also cause a greater flow of blood through the brain and a lesser flow through the muscles, though this latter effect is not of great moment in working muscle. These reactions shunt blood from working muscles, where oxygen would be used rapidly, and preserve the oxygen for use in the brain, where no oxygen debt can be incurred. They divide the whale into two parts: a muscular compartment effective for work, and a heart-and-brain compartment essential for life.

A FINAL point in reference to the duration of dives concerns the amount of oxygen a whale may take with it after its last inspiration at the surface. Even with the advantages of shunting blood just described, a whale must have adequate oxygen to stay alive. Man possesses little capacity to store oxygen. After a deep breath, the lungs of a 150-pound man contain 900 c.c. of oxygen, the blood, 1,150 c.c; the tissues and tissue fluids, about 250 c.c. This makes a total of approximately 2,300 c.c. of available oxygen. During very moderate work this supply lasts about four minutes.

The Danish physiologist August Krogh has estimated the oxygen capacity of a whale He calculated that an 89-foot blue whale weighing 268,409 pounds had an oxygen storage capacity of 2,800,000 c.c., and that swimming under water at three knots it consumed 53,000 c.c. of oxygen per minute. Thus it stores enough oxygen for a 50-minute dive without overexertion. The figure checks well with the various estimates of how long a blue whale can stay under water. In normal feeding the whale usually remains submerged for 10 to 20 minutes, then surfaces and blows four or five times to fill its lungs completely with fresh air.

Whales, as contrasted with man, store proportionately greater amounts of oxygen in their lungs, blood, respiratory pigments, muscle and fat. They also possess another storage mechanism networks of small arteries and large veins embedded in fat at the base of the brain, in the chest and in the region which corresponds to the groin in man. These networks, called *retia mirabilia,* constitute a very considerable reservoir of oxygenated blood surrounded by fat, in which oxygen is quite soluble. The blood is saturated with oxygen, and further supplies of oxygen can diffuse into it from the surrounding fat

The second of our questions—how whales avoid air embolism—is fully as interesting as the first. We have noted that the body of a diver at 100 feet contains four times more dissolved nitrogen than it does at the surface. Obviously two factors determine the amount of oxygen dissolved from the lungs into the blood. The first is the depth reached, and the second is the length of time the diver stays at this depth. If a man remains for an hour at 100 feet, he must be brought up very slowly to breathe off the excess nitrogen that has accumulated in his body. Here the whale has a physiological advantage. With submergence and with the shunting of blood from muscles to more vital parts, the whale's heart slows and the flow of blood through its lungs is reduced. Thus less nitrogen dissolves into the blood from air in the lungs than at the surface, where the heart beats more rapidly.

Time is required for nitrogen to enter blood from the lungs. If a diver's stay at depth is brief, he may ascend very rapidly and experience no ill effects. A. R Behnke of the Naval Medical Research Institute has found that a diver can go down to 300 feet, remain one minute and come to the surface at a rate of 25 feet a minute without suffering bends. He may remain at 100 feet for 25 minutes and return to the surface at a similarly rapid rate.

The situation of the diver is quite different from that of the whale, in that he is receiving surface air pumped to him at a pressure corresponding to his depth. The air-absorbing surface of his lungs remains the same as it is out of water. The whale, on the other hand, takes its air down with it and can obtain no more until it again surfaces. The round, well-supported chest of the whale can doubtless sustain great pressure without diminishing in size, but this is not true of its abdomen. As the whale dives deeper and deeper its abdomen is compressed, its diaphragm is forced up and its lungs become smaller and smaller. The diving whale's lungs contain only the nitrogen of the air breathed at the surface. There is no continuous supply of nitrogen under pressure to multiply the amount of the gas dissolved in its blood and tissues.

On the other hand, the whale has a vast reservoir of fat in its blubber. This has poor circulation, has no function immediately vital to the whale, and has a marked capacity for nitrogen solution. Our best explanation at the present time as to why whales rarely suffer air embolism is that the alveoli, or air sacs, of the lungs are continuously compressed as the animal goes down and their walls are thickened, rendering absorption of nitrogen taken from the surface increasingly difficult. The slowed circulation during submergence also lessens absorption.

WHEN a whale emerges from a dive, its circulation accelerates with the more rapid beat of its heart, and its lungs return to normal size. These reactions probably cause nitrogen to be eliminated so rapidly that the blood cannot become saturated with the gas to a point where bubbles would form. Although excess nitrogen dissolved in blubber may not be able to diffuse into nearby blood vessels rapidly enough to prevent some localized bubbling, the effect can do no harm unless it occurs on a large scale. The bubbles will gradually disappear when the whale rises to the surface. Scholander showed that a seal lowered to 984 feet in three minutes and drawn up in nine minutes—a total diving period which is not unusual for this animal—died promptly from bends. He also reported, as previously indicated, the death of a fin whale from the same cause. Thus it appears that diving mammals, extraordinarily adapted as they seem to be to survive prolonged submergence, are not completely immune to bends.

Laurie has reported finding spherical microorganisms in the blood of Antarctic whales, both the blue and fin varieties. These minute creatures caused the disappearance of nitrogen from blood and culture media. He suggests that they may be important in reducing the amount of the whales' dissolved nitrogen, particularly in repeated dives, and so diminishing the danger of bends. While Laurie's findings and suggestions are attractive, they have not been confirmed and we are left with the conclusion that whales, and diving mammals in general, differ from man in their resistance to the lack of oxygen and to dangerous bubble formation because of specialized quantitative differences in their physiological capacities, and not because of mechanisms representing new and unusual developments.

Cecil K Drinker, now retired, was formerly professor of physiology at the Harvard University School of Public Health.

BOOKS

Two historic scientific institutions and their place in the development of science in the U. S. and England

by I. Bernard Cohen

SCIENTISTS AND AMATEURS THE HISTORY OF THE ROYAL SOCIETY, by Dorothy Stimson. Henry Schuman ($4.00)

SONS OF SCIENCE. THE STORY OF THE SMITHSONIAN INSTITUTION AND ITS LEADERS, by Paul H Oehser. Henry Schuman ($4.00).

THE recent publication of histories of the Royal Society of London and of the Smithsonian Institution focuses attention on two important problems of organized science the relation of government to the scientific enterprise, and the function of scientific institutions.

The *sine qua non* of scientific progress is the publication and dissemination of the results of research. Today at least the facilities for such dissemination are available, although in practice communication is restricted by the existence of "industrial secrets" and by the increasing number of topics classified for national security. Until very recently, a grave concern was the almost unmanageable flood of new material; much thought had been given to better abstracting services, cheaper and more readable formats, and the new processes (*e g.*, microfilm) that seemed in some instances about to replace printing altogether.

Before the late war a scientist who wanted to publish a paper on recent work simply chose one of many appropriate journals. That a great number of journals are published by academies, societies, and other groups, is in itself evidence of the large-scale aspect of modern scientific enterprise. This, however, is a relatively recent development. We have only to go back some 300 years to find a time when there were no scientific journals at all and when the publication and dissemination of the results of scientific research presented a difficult problem for the investigator. Much of the story is told in Dorothy Stimson's new history of the Royal Society.

As a sample of scientific communication three centuries ago, consider how young Blaise Pascal learned about the exciting new discoveries of Galileo's pupils Torricelli and Viviani, who had just made the famous experiment demonstrating the effects of air pressure. Pascal's brother-in-law Perier informs us that the first man in France to learn of the famous "Torricellian experiment," made with a glass tube and a dish of mercury, was Father Mersenne of Paris He received the news by letter from Italy in 1644 and immediately passed it on to his many correspondents, the result was that it took two years for the experiment to become "famous throughout the country to the admiration of all scientists." One of those who heard of the work from Mersenne was Pierre Petit, Chief of the Department of Fortifications, who in turn told Pascal about it. Pascal and Petit reproduced the experiment in Rouen in 1646 and, in the following years, Pascal made his own experiments extending the Italian studies.

At the same time, in 1645, a group of young men in London felt the need of learning the news in science by a better means than letters, a chance encounter with a new book or tract, or the unreliable accounts of travelers. They formed a kind of weekly luncheon club to share and discuss what each had learned. The conversation was limited to the "new science": "Physick, Anatomy, Geometry, Astronomy, Navigation, Staticks, Mechanicks, and Natural Experiments." ("... we barred all Discourses of Divinity, of State-Affairs, and of News other than what concern'd our business of Philosophy.") They discussed the circulation of the blood, the Copernican universe, comets, the satellites of Jupiter that had been discovered by Galileo, telescopes, the weight of air, falling bodies and kindred subjects. Robert Boyle referred to the group as "the invisible college," and it has been known by that name ever since.

During the years of Cromwell, some members of the group went to Oxford, where they replaced certain royalists, after the Stuart Restoration in 1660 they in turn were removed, and they rejoined their former associates in London. It was now decided to create a more formal organization and to attempt to gain the patronage of King Charles II; the successful outcome of this plan marked the official establishment of the Royal Society in 1662. Although the new society was favored by royal patronage, it received no royal funds for its many undertakings.

Soon after the establishment of the Royal Society an extensive and regular correspondence was begun among the members, their friends, and interested parties, both in England and abroad. In contrast to the letters from Mersenne to his friends these were not personal letters, but rather "epistolary dissertations" The method was laborious and cumbersome, and it did not serve when the inevitable arguments arose over priority in discovery. Hence there was founded a Society journal, *The Philosophical Transactions of the Royal Society*, known throughout the English-speaking world as "Phil Trans." The journal was at first a private venture on the part of Oldenburg, the Society's first secretary. It was almost as if it was easier for Oldenburg to print a kind of monthly report on the activities of the Royal Society than to write a detailed letter to Spinoza and many other correspondents who wanted to know what was going on.

The author of the present history of the Royal Society was for many years Dean of Goucher College and is at present chairman of the Goucher history department. She has long been interested in the problem of educating young women in science by means of history, and she has for many years taught a well-known course on the history of scientific ideas. Trained as an historian rather than as a scientist, she brings to her book a wealth of knowledge and insight into the development of ideas and the relation of science to culture. The title of her book reflects the early character of the Society: it included men who were scientists in the present sense (Hooke, Wallis and Boyle) and also those who either dabbled in science or who were at least sufficiently enamored of the "new philosophy" to try learning how the world could be understood by experiment rather than by syllogism.

The author describes in great detail the early years of the Society. Her account of the period illuminates its personalities and issues; but I have the feeling that the background of history, ideas, personalities and administrative events has swallowed up the achievements of the Fellows of the Royal Society. In 1663 Robert Hooke drew up the following memorandum.

"The business and design of the Royal Society is.

"To improve the knowledge of naturall things, and all useful Arts, Manufactures, Mechanick practises, Engines and Inventions by Experiments—(not meddling with Divinity, Metaphysics, Moralls, Politicks, Grammar, Rhetoric or Logick).

"To attempt the recovery of such allowable arts and inventions as are lost.

"To examine all systems, theories, principles, hypotheses, elements, histories, and experiments of things naturall,

mathematicall and mechanicall, invented, recorded, or practised by any considerable authors ancient or modern. . . ."

This was a concise statement of the aims of the new body; I, for one, would have liked Miss Stimson to have shown the extent to which they were realized. One of the interesting aspects of Hooke's account is that it shows the considerable degree to which the aims of the new Society were inspired by Francis Bacon who in his *New Atlantis* had described a visionary scheme for assembling and studying scientific information of all sorts Bacon also influenced the Society by his insistence on the importance of applying science to practical arts

By the 18th century the Royal Society was more of an accepted body than it had been a hundred years earlier. While most of the controversies that marked its foundation had died out, at least one worthy opponent of the Society, "Sir" John Hill, mercilessly exposed some of the absurdities and trivia that appeared in the *Philosophical Transactions*—a description of a merman, the transmutation of water into maggots, and "incontestable proofs of a strange and surprising fact, namely, that Fish will live in Water." Although at this time the membership was far from being confined to scientists in the strict sense and the *Philosophical Transactions* published some nonscience and nonsense, a good proportion of the Society's activities and publications were devoted to good science. Furthermore, by publishing papers from colonials the Society acted as a scientific center for the whole Empire. It was to a large degree responsible for the scientific activity of many Americans, including Benjamin Franklin.

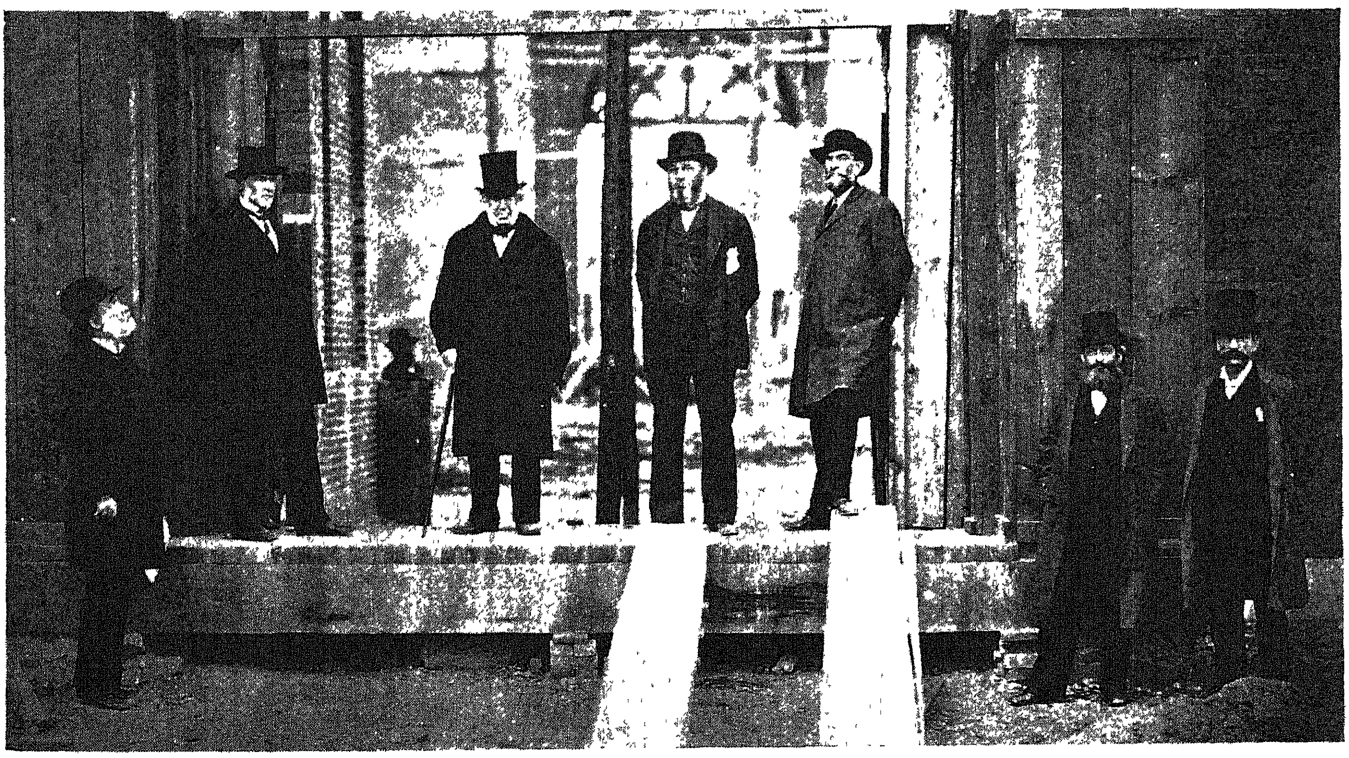
The author points out the importance of the Royal Society to colonial science, but her account is weakened by neglect of the true scientific achievements of the colonial Fellows of the Royal Society, as well as of later Americans. Had she written, for example, that Cotton Mather contributed the earliest recorded observation of plant hybridization, and that he was the author of the first general book on the sciences by an American, his election to the Society would take on more significance We are not told that Thomas Brattle's astronomical observations were used and acknowledged by Newton in his *Principia*, also omitted, for the later period, is any mention of Benjamin Peirce's (misspelled as Pierce) great original contributions to mathematics, or the fact that Nathaniel Bowditch's reputation as a scientist depended more on his translation and annotations of Laplace's *Mécanique céleste* than on his *Practical Navigator*.

As science itself became an established and clearly defined profession, it was clear to many Fellows that the Royal Society must rid itself of dilettantes and amateurs. Begun in the 1830s, the transformation of the Royal Society into a truly professional scientific body coincided with the growth of the British Association for the Advancement of Science and with the period of reform in British government and life.

We need not follow the author's story into the recent past and the present. It must be said that the early part of the book is more exciting than the latter, which becomes almost completely an account of administrative developments. Indeed, the book invites criticism for the extent to which it is an administrative or anecdotal history. Writing more for the layman and the historian than the scientific specialist, the author has devoted relatively little space to the scientific research of the Fellows of the Royal Society and to Society-sponsored investigations and expeditions

Leibnitz appears only once in these pages, as a constructor of calculating machinery, not a single line being devoted to his place in the "age of genius" (the discussion of which occupies more than a third of the book). There is no reference to the famous quarrel as to whether Leibnitz or Newton devised the calculus. Furthermore, the role of the Royal Society in the history of science, as well as in the history of Western culture and civilization, could have been made much clearer by some parallel accounts of the activities and histories of other scientific academies.

THE story of the Smithsonian Institution, written by Paul H. Oehser, helps fill a long-felt need for adequate histories of American scientific institutions. Oehser has been affiliated with the Smithsonian since 1931, as Assistant Chief of its Editorial Division. He wisely begins his history by describing what the Smithsonian is and does today, and showing how the terms of James Smithson's will have been realized. Smithson



U. S. NATIONAL MUSEUM, which is one of the Smithsonian Institution's 10 "bureaus," was under construction in 1879. Second from left in this photograph is General William T. Sherman, who was Regent and Chairman of the Building Committee. Fourth from the left is Spencer F. Baird, Secretary of the Smithsonian.

desired "to found at Washington an Institution for the increase and diffusion of knowledge among men," and the following 10 "bureaus" today make up the Smithsonian family (partly or wholly supported by Congressional appropriations): the U.S. National Museum, the International Exchange Service, the Astrophysical Observatory, the National Collection of Fine Arts, the Bureau of American Ethnology, the National Zoological Park, the Freer Gallery of Art, the National Gallery of Art (under a separate board of trustees), the National Air Museum, and the Canal Zone Biological Area.

The history of the Institution begins with a short biographical sketch of the strange man who founded it Smithson was the illegitimate child of the first Duke of Northumberland; his mother was descended from Henry VII. A precocious student of science, he was elected a Fellow of the Royal Society of London 11 months after he received a Master of Arts degree from Pembroke College, Oxford, in 1786. Smithson bitterly resented the loss of his ducal birthright—a resentment reflected in the following comment from one of his manuscripts: "The best blood of England flows in my veins· on my father's side I am a Northumberland, on my mother's, I am related to Kings, but this avails me not. My name shall live in the memory of man when the titles of the Northumberlands and the Percys are extinct and forgotten."

Smithson left his entire property to his nephew, but for some reason that has never been ascertained he decided that, if the latter had no children, all but a small annuity should go "to the United States of America" for an institution. Smithson died in Italy in 1829, and when his nephew died six years later without wife or children the U.S. fell heir to an estate worth about half a million dollars. President Andrew Jackson announced the gift to Congress on December 17, 1835. That started 10 years of debate and discussion over the form of institution to be established.

Oehser describes the actual organization of the Smithsonian Institution in a chapter devoted to its first Secretary, Joseph Henry. The treatment here, followed closely in the succeeding chapters, is to give a thumbnail biographical sketch of the man, then an account of his scientific work and reputation, followed by a story of what happened in the Institution during his tenure of office. Thus the main part of Oehser's history falls into chapters devoted to Henry and his successors: Spencer Fullerton Baird, Samuel Pierpont Langley, Charles D. Walcott and C. G. Abbot, and another chapter for Charles Brown Goode, who is chiefly responsible for the direction followed by the new National Museum.

Under Joseph Henry's guiding hand, the Smithsonian set out to increase knowledge by stimulating men of talent to do original research, offering rewards for such activity and publishing the results in a series of memoirs aptly called *Smithsonian Contributions to Knowledge* Henry's plan was adopted in 1847 and the Institution was ready to go to work. America now had a national scientific institution, but notice that it was the result of a private gift rather than a government expenditure

It is greatly to be regretted that Oehser, by writing largely in terms of personalities, has neglected the broad historical background so skillfully woven into Dorothy Stimson's history of the Royal Society Greater emphasis might well have been given efforts before 1847 to interest the U.S Government in sponsoring scientific activity. Throughout the first half of the 19th century several attempts were made to form a national organization for the advancement of American science with Federal support and patronage. All these attempts failed. The Smithsonian was a different kind of body, a sort of private foundation within the Federal structure. Over and over again men like Joseph Henry, Alexander Dallas Bache, and Charles Henry Davis pointed out the need for a truly national scientific body, as opposed to private or semilocal autonomous groups such as the American Philosophical Society in Philadelphia and the American Academy of Arts and Sciences in Boston. England had its Royal Society, France its Academy of Sciences, but where was a similar body for the U.S.? While the failure to establish a National Academy of Sciences until the Civil War may be due in part to a fear of centralization in government, it also reflects the impotence of American science in general and the low opinion of research in the minds of all but a very few national leaders.

During the early days of the Civil War, and before the establishment of the National Academy of Sciences, the Smithsonian undertook many kinds of war research It was again drawn into such work during the Spanish-American War. Its secretary was Langley, known for his work on the heat-measuring bolometer, solar radiation and other aspects of astrophysics. He had just completed his experiments on flight and, having built a small model which flew under its own power for a very short distance, undertook to construct a full-sized machine for the War Department. The failure of this attempt won it the nickname "Langley's folly," and later involved the Smithsonian in a heated priority argument with the Wright brothers. Fortunately for all concerned Dr. Abbot, who recently retired as Secretary, made the necessary amends, and established the claims of the Wright brothers without impugning Langley's actual contribution.

The limited scope of Oehser's book has not permitted him to evaluate the different activities of the Smithsonian Institution and to compare them with those of other groups. The story is told in isolation, almost as if it were an historical guidebook. It serves the welcome purpose, however, of recording the work of a major scientific institution and providing a convenient and readable cross section of the history of American science.

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TORCHBEARERS OF CHEMISTRY, by Henry Monmouth Smith. Academic Press, Inc ($8.00) An interesting collection of some 250 portraits of the major contributors to modern chemistry. There are brief biographical notes and a useful bibliography of biographies. Figuratively, if not literally, the lives and habits of most of these men and women are well described in Paracelsus' lines. "For they are not given to idleness, nor go in a proud habit, or plush and velvet garments, often showing their rings upon their fingers, or wearing swords with silver hilts upon their sides, or fine and gay gloves upon their hands, but diligently follow their labors, sweating whole days and nights by their furnaces. . . They put their fingers amongst coals, into clay and filth, not into gold rings. They are sooty and black like smiths and colliers, and do not pride themselves upon clean and beautiful faces."

NEW WORLDS EMERGING, by Earl Parker Hanson. Duell, Sloan and Pearce ($3.50). Professor Hanson takes the bright view in this geo-economic and geo-political study. The fear of war, he thinks, is greater than the threat, man is in no danger of starvation, and the road to survival is broad and certain: neither capitalism nor free enterprise are doomed, though they must adjust to the requirements of a growing world, vast areas in the North, in Africa and in Latin America, which men have just begun to develop, hold resources sufficient to meet every foreseeable need of the colored as well as the white races. Although the clichés are pretty thickly spread, this is a cheerful and not unreasonable book.

HISTORICAL INTRODUCTION TO MODERN PSYCHOLOGY, by Gardner Murphy. Harcourt, Brace and Company ($6.00). A revised and considerably enlarged edition of a work highly regarded since its first appearance in 1929. Dr. Murphy has brought his book up to date by adding chapters on behaviorism, modern conceptions of association, Gestalt, field theory, Freud, and other material about the newer directions of research in child psychology, social psychology, intelligence measurement and the like. The newness of at least one of the more recent departures is set in

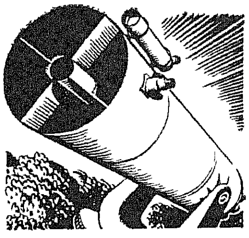
perspective by Murphy's quotation from Aristotle. "Well-educated physicians, at any rate, say that we should pay close attention to dreams." An excellent study of the background of the most controversial and fluid of contemporary sciences.

ENCYCLOPEDIA OF CRIMINOLOGY, edited by Vernon C. Branham and Samuel B. Kutash. Philosophical Library ($12.00). PHOTOGRAPHY IN CRIME DETECTION, by J. A. Radley. Chapman and Hall Limited, London (21 shillings). The first of these books has contributions by leading authorities on a variety of subjects related to the nature, causes, prevention and treatment of crime. It runs from abandonment, abduction and abortion through barratry, embracery, the FBI, Freud, Hippolyte Villain, irresistible impulses, marihuana, pedophilia, prison management, treason, voyeurism, the Wild Beast Test, and youth correction. It becomes quite clear from these pages that if a policeman's lot is not a happy one, neither is that of the conscientious judge, warden or other specialist seeking to deal fairly with the problems of crime. Subject to the usual limitations of works of this kind, the articles being uneven and many of them so brief as to be almost meaningless, this is a useful compendium of widely scattered knowledge. The bibliographies are distinctly helpful. Radley's book is full of stuff which should appeal no less to the home detective than to the professional sleuth. It consists in photographs of time bombs, booby traps, weapons, counterfeit coins, forged wills and other documents; examples of the use of ultraviolet and infrared light and photomicrography in investigating cases of assault, burglary, murder and rape; and an accompanying text describing, with reference to numerous actual incidents, methods used by British and American police.

SWEEPER IN THE SKY, by Helen Wright. The Macmillan Company ($4.00). A short, mostly personal biography of Maria Mitchell (1818-1889), America's first "lady astronomeress." Born in Nantucket of Quaker parents—her father was an amateur astronomer of considerable skill—she was largely self-educated, became famous at 29 for discovering the comet later named after her, was a computer for the Nautical Almanac and the Coastal Survey, the first and beloved professor of astronomy at Vassar Female College, and a leader in the women's rights movement of her day. Of this admirable, honest and lonely woman, who long "lived alone with her constellations," there is a charming description by Julian Hawthorne, Nathaniel's son (she knew the family well, having traveled with them abroad): She had . . . "a fine, aromatic New England quality . . . a woman of unusual intellect and character . . . [with] an immense, healthy curiosity . . . a great flow of native, spontaneous humor . . . old fashioned yet full of modern impulses and tendencies. Though bold as a lion, she was nevertheless beset with the funniest feminine timidities, and misgivings, due mainly, I suppose, to her unfamiliarity with the ways of the world." Reverential and somewhat overwritten, with a heavy dose of exclamation marks, but an interesting book.

THE SPHERE OF SACROBOSCO AND ITS COMMENTATORS, by Lynn Thorndike. University of Chicago Press ($10.00). Professor Thorndike, noted for his medieval studies, among them the monumental *A History of Magic and Experimental Science,* has edited the Latin text, with contemporary commentaries and English translation, of this famous astronomical and cosmographical work. John of Sacrobosco, thought to have been born in the English town of Holywood, wrote his treatise on spheres (material and "supercelestial"), circles, planets, "diverse localities" and their "climes," and the "causes of eclipses," in the early part of the 13th century while teaching at the university in Paris, the city where he spent most of his life. Its "clear, rapid" and elementary presentation led to the adoption of the work at Paris, Vienna, Prague, Oxford, Bologna and other universities, where for four centuries it remained the standard reading and lecture text prerequisite for the Bachelor or Master of Arts degree. Of the numerous commentaries, modifications and successor treatises, several principal examples are now reprinted. A scholarly book, of first importance to the historian of science.

THE CHEMICAL ARTS OF OLD CHINA, by Li Ch'iao-p'ing. Journal of Chemical Education ($5.00). In the category of vague beliefs widely held, there is one (folklore about the Mysterious East) to the effect that much of applied science as known 50 years ago had been anticipated by the Chinese long before the Middle Ages. The author of this book, professor of chemistry at National Northeastern University in Mukden, dispels this romantic notion, though he supports the claim that at least one contemporary blessing, gunpowder, was invented during the Sung or Southern Sung Dynasty in the 12th century. Somehow it then found its way to the Arabs, to Roger Bacon, to Berthold Schwartz and to the battle of Crécy. The author's overly brief but interesting history describes various branches of ancient Chinese chemistry, including alchemy (as befits true wisdom, the Chinese alchemists were more interested in making *chin tan,* an elixir to prolong life, than in making gold), metallurgy, salt-making, ceramics, pyrotechnics, tanning, and the manufacture of lacquers, colors, wine, paper and incense. A handsome volume, copiously illustrated with plates and old cuts.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

AS a result of the recent sale of a large number of war-surplus Pyrex telescope blanks with the uncommonly large diameter of 16 inches, 16-inch telescopes should soon become fairly common among amateurs. With smaller sizes it is customary to grind the mirror disk against a tool disk of equal diameter, but to stroke one 50-pound, 16-inch disk across another requires more brawn than many possess.

Dr. Robert E. Smith of Sacramento, Calif., has devised a simple, workable way to reduce the weight of the disk any desired amount by means of a variable counterweight. As shown in the illustration on the opposite page, the counterweight is a receptacle suspended from a steel cable over two pulleys at ceiling height. It is attached to the mirror by suction cups of the kind used to fasten skis to automobile tops.

"When dampened with glycerine these cups really stay put," Dr. Smith reports, "yet they are easily removed with a knife blade." Just above the cups is an attachment for the cable, consisting of a ball-and-socket joint and a small tapered pin to facilitate detachment. Above this is a swivel, and then the cable. On the counterweight side of the cable is a scale for measuring the weight put into the receptacle beneath it. "My idea works," Dr. Smith declares. "I can handle the 16-inch disk as easily as I can an eight-inch in the ordinary way."

In further description of the illustration, he adds, "The man seated at the grinding pedestal is Harold Simmons, president of our Sacramento Valley Astronomical Society. A small motor near his feet slowly rotates the pedestal, so that he or I can grind in comfort."

Instead of standing and walking around the grinding pedestal, Lyle A. Ellis of Spokane, Wash., enjoys the sybaritic luxury of the mechanism shown in the illustration on page 62. "You sit," he writes, "on the embroidered feather pillow at the end of the jib arm, and kick yourself around the pedestal, which is a length of three-inch pipe set deep in the earth. To the top of the pedestal is welded a 1½-inch pipe flange to receive the pipe fittings of the grinding tool (and of the mirror, whenever it is desired to shallow the curve by working with the tool on top). Surrounding the central pipe, beneath the pan for catching drippings, is a length of five-inch pipe. This rides on a large ball bearing at its bottom. The lateral thrust forces due to the worker's weight are transferred to the central pipe member through slots in the outer pipe, by means of two pairs of ball bearings that are mounted on stub shafts welded to the outer pipe."

W. H. Newman of Ditchling, England, accomplishes the occasional rotation of the tool by mounting it on top of a vertical spindle that has a broad wooden disk near floor level which is turned occasionally with the feet.

The relatively simple arrangement shown in the illustration on page 63, a sketch by the late Russell Porter, is used by James J. Pflaum of Dayton, Ohio. It enables the mirror maker to sit in a chair with his work on another chair or a box, and grind as good a mirror as if he stood up and walked round a pedestal, though he loses the fun of building a more elaborate rig. If now and then he unhooks the spring rod and rotates the mirror, he will get good results.

Rotating the mirror or "walking round the barrel" can be greatly overdone, though no harm will result and the worker may even gain needed exercise. Until last-stage grinding neither component motion need scarcely be thought of. Of the two, the rotation of the mirror is the more important. So long as no deliberate pains are taken to replace the mirror always in the same position, accident alone will rotate it enough, just in the way it happens to be picked up and replaced on the tool. Increased care may be taken toward the end of grinding, and again of polishing, to ensure that it is rotated fairly often.

Now consider the tool. Suppose that it were never rotated at all, and that the worker did not walk around it. As a result of the uneven application of pressure, it would grind too low on one side, but no great harm would be done. Devices for turning the mirror by exact angular fractions of 360 degrees have sometimes been devised. These tend simply to defeat the randomness of the rotation when no thought is given to the matter.

Some workers have taken the "ring-around-a-rosy" principle of grinding so seriously as to perform a kind of dance, taking one step around the pedestal for each stroke of the hands. This is mostly superfluous, but it may keep the worker's weight down. During most grinding and polishing the author takes about 16 strokes at each position without bothering to count the strokes. Even this is fewer than need be, but it changes the scenery.

An interesting contribution to the lore of telescope making might be made by some inquiring mind. First he would rotate neither mirror nor tool, and see just how astigmatic the mirror would come out. Then he would rotate the mirror but not the tool, and measure the runover-heel effect on the tool.

WHOEVER seeks to learn the best *magnifying powers for telescopes* should be prepared to do much scattered reading, find varying and contradictory statements and in the end not find the concise, unqualified answer he probably had hoped for. A correspondent of this department writes that he has been through all this, has waded through the literature, found it vague and confused, but has finally found *terra firma*. "This confusion," he states, "is surprising, since there is a very simple mathematical formula, based on elementary physics and the anatomy of the human eye. The answer is clear and definite. The problem involves only two factors, the resolving power of the objective and the acuity of the eye.

"The resolving power of the normal eye is one minute of arc. The best power of a telescope is attained by the combination of objective and eyepiece focal length that causes the resolving power of the objective and eye to match. To determine this we merely divide the 60-second resolving power of the eye by the 4.56 seconds per inch of aperture of the familiar Dawes formula for separating power. There is only one definite answer. The best power is seen to be 13.16 times the aperture of the telescope in inches."

The return to *terra firma* is indeed concise, and free from encumbering modifications of the kind that irritate the tidy mind. If we examine the literature of observing, however, we find that observers have been using magnifications far in excess of this rule—as high as 35 or 40 diameters per aperture inch of the telescope for planetary observation, and even higher, 50 or even 70 diameters per inch, for double star observation.

Something must be wrong. It is this: the satisfying rule just stated refers only to the magnification that fully exhausts the objective's resolving power—its power to bring out all the detail in the image it forms. This is explained in D. H. Jacobs' *Fundamentals of Optical Engineering*, where the same figure, 13 diameters, is reached. While this is not the figure at which we shall finally arrive, it is well worth remembering—provided we also remember, first, that it is valid only for point objects having equal brightness, and second, that many astronomers do not accept the one-minute resolving power of the eye, which appears to be based on ideal data obtained in the laboratory by physiologists and ophthalmologists.

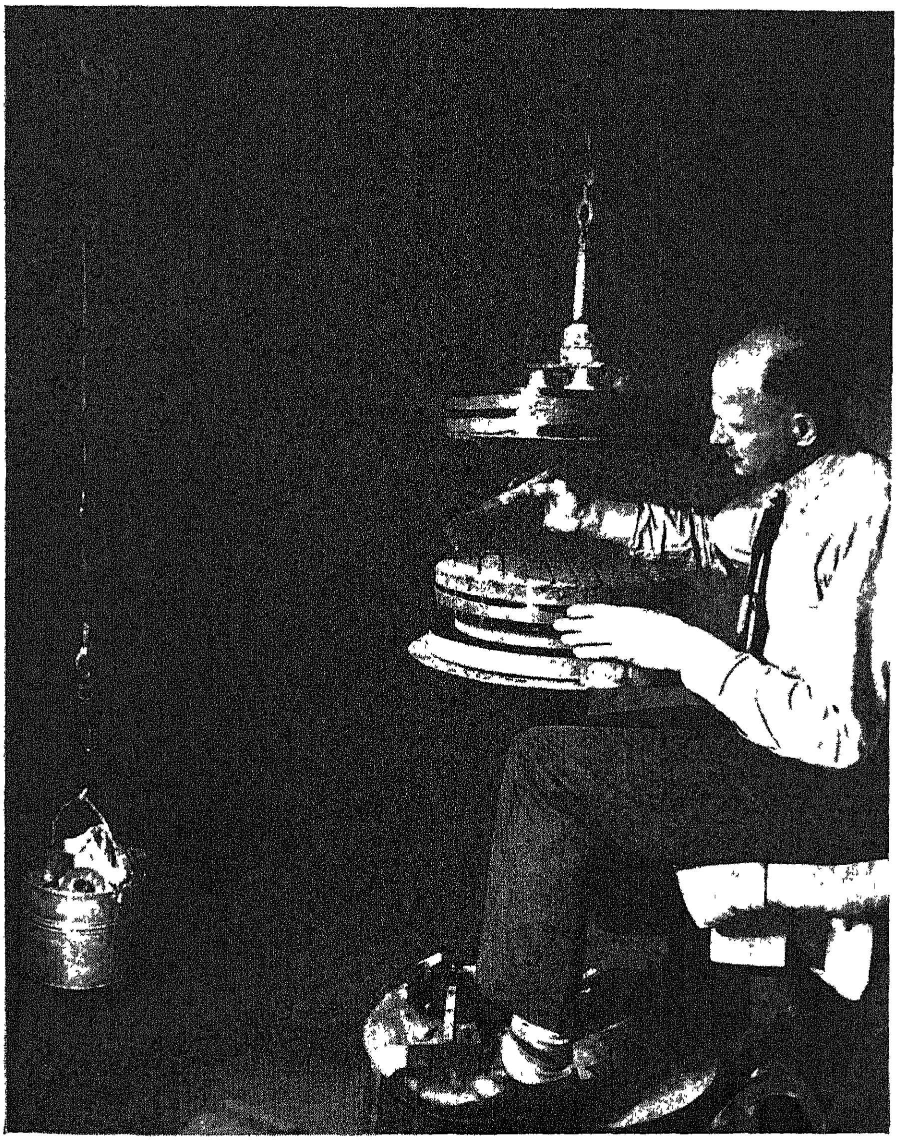
The textbooks tell us that any magnification beyond this 13 diameters per

inch of aperture is "empty". it brings out no new details of the image, no matter how much higher it is raised. The word empty has a certain connotation of the unworthy, and has sometimes been used in a derisive sense. For example, a proposal received years ago by this department, to compound 10 compound microscopes and thus magnify a billion diameters, brought forth derision, for this was empty magnification at its very worst.

Nevertheless, the whole experience of observing astronomers goes to prove that empty magnification of already resolved images needs no apology, but is even a necessity, up to the point where atmospheric conditions cause the image to lose more by blurring than it gains by *increased ease of vision*—which is the kernel of the whole matter. The blurring point varies with the seeing conditions and somewhat with the aperture of the telescope. For amateur-size telescopes and ordinary atmosphere it runs from two to four times the resolving magnification of 13. A formula for useful magnification quoted in L. Bell's *The Telescope* is 140 times the square root of the aperture. This would be 35 diameters per inch of aperture on a 16-inch telescope, 47 on a nine-inch and 70 on a four-inch. This is not a rule, but an abstraction from the reports of expert double star observers who had set the magnification empirically wherever they found it best. Your own "rule," similarly, is wherever you get the best results.

In *The Binary Stars*, Director Robert G. Aitken of Lick Observatory emphasizes "Use the highest power the seeing will permit." For the planets, the astronomer Bernard Lyot found at Meudon near Paris that in a refracting telescope the minimum magnification to show the finest details accessible on the best nights was 37 per inch on a four-inch, 35 on an eight-inch, 27 on a 12-inch and 20 on a 24-inch. In Arizona's atmosphere, on an 18-inch refractor, Percival Lowell most commonly used 24 to 34 diameters per inch on planetary work. Lyot says that for planetary details, which generally show low contrast, the limits used on double stars are a bit too high.

In this connection a statement by Dr. W. H. Steavenson of Cambridge, Eng-



Counterbalancing pulleys and weight for a heavy mirror

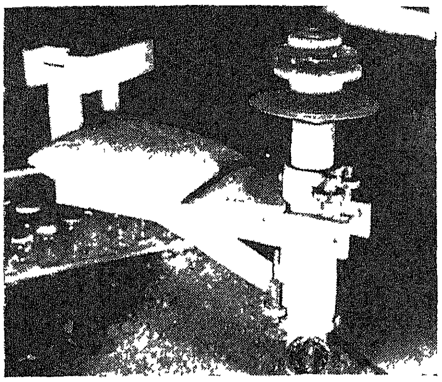
land, in *The Journal of the British Astronomical Association* is of interest 'Very few textbooks point out that the Dawes formula is not applicable to planetary detail, or give the reason for this. Cassini's division in Saturn's ring and the shadows of Jupiter's satellites, both visible with apertures between two and three inches, are well-known examples of the relatively superior resolving power of a telescope when applied to planets. Experiments have often been made on terrestrial objects also, and give similar results. Recently I have myself found that a black dot on a white ground is visible when subtending an angle about one third of that corresponding to the Dawes formula, and I find that Sir William Herschel obtained a similar result in 1804. For a dark line, visibility is attained at an angle something like one fifth of the Dawes limit. The reason for the apparent discrepancy is, in the main, the low intensity of the illumination of planetary surfaces, each element of which has consequently a relatively small spurious disk."

INVITED to contribute his experiences in observational work to the present discussion, Rolland R. LaPelle of Longmeadow, Mass , a well-known amateur astronomer, writes:

"In estimating the resolving power of a telescope most of us tend to fall back on the classic expression of Dawes, an empirical formula relating the resolving power of its objective to its diameter, thus: $R=4.56/D$, where R is the resolving power of the objective for moderately bright double stars expressed in seconds of arc of separation, and D is the diameter of the objective in inches.

"Actually this expression is correct for stars of only one color, the yellowish type G, similar to the sun. The expression may also be taken to represent the diameter of the spurious disk which is the stellar image, out to the center of the dark space midway between the disk and the first bright ring. The spurious disk will, however, be much larger, by a factor of at least two, for very red stars of type M and later, and smaller by an almost equal factor for very blue stars of type B. Further, the diameter of the spurious disk, *as the eye perceives it*, will be greater, because of irradiation, for very bright stars, and smaller, because of the lack of light, for very faint stars. Hence for very bright blue, or moderately bright or very bright red stars, we cannot expect to reach Dawes' limit, while for moderately bright blue stars (but not for faint ones, because of the deficiency of light) we may do considerably better than Dawes' limit.

"If we assume Dawes' limit as a median value, however, we may then ask what power will be necessary in our eyepiece to render the two stars visible. This factor again is uncertain, since the resolving power of the human eye is a



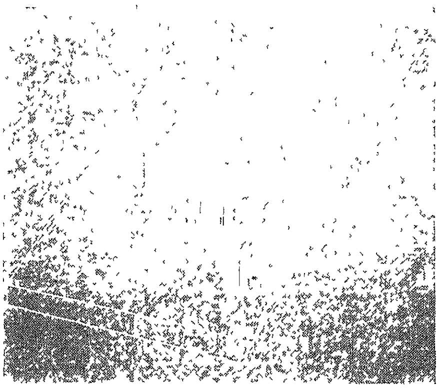
A mirror-grinding luxury

much-disputed question It is said that the ophthalmologists base their charts upon the assumption that the eye can resolve objects separated one minute of arc. This may be true for nearby bright objects, but a search of astronomical textbooks yields a somewhat different result J. C. Duncan's *Astronomy* states that the astronomical resolving power of the eye is between three minutes and three minutes, 30 seconds, and uses a value of three minutes. Bell, in a quite thorough discussion in *The Telescope*, states that those of fairly keen vision can distinguish the two stars of Epsilon Lyrae, separated three minutes and 27 seconds, while he has never known anyone who could separate the two components of Asterope, two minutes and 30 seconds apart. He then uses a value of five minutes in his calculations.

"From my observations with a six-inch telescope, I believe my own constant is between two minutes, 30 seconds, and three minutes. It is important to state the diameter of the objective, since with a larger instrument having greater resolving power less magnification is required. Thus, while the closer pair in the double-double, Epsilon Lyrae, requires at least 75X in my six-inch, giving them a separation of 75X 2.6 seconds or 195 seconds (three minutes and 15 seconds), they are readily perceived in a 10-inch at a power of only 48X. This illustrates the well-known impossibility of setting up an absolute constant for all sizes of objective, even though the constant supposedly refers only to the eye of the observer.

"If, however, we are dealing with stars separated by Dawes' limit for the particular size of objective in use, then the spurious disks will be of the same diameter, regardless of the objective size. If we assume that the average human eye, under these conditions, requires 200 seconds of separation for stars of median brightness and of yellow color, then the power required will be $200/(4.56/D)$, or $44\,D$ That is, to split stars at Dawes' limit of resolution to a point where they may readily be perceived by the normal eye, the magnifying power must be 44 per inch of objective diameter.

"How does this check with the practice of skilled observers? In *The Tele-*



Simplest grinding rig of all

scope Bell summarizes the findings of a paper by T. Lewis, published in *The Observatory*, in which that author tabulated the most often used power of a large group of professional observers. With telescopes of moderate size powers around 50 per inch of aperture were usual, and now and then on special occasions up to 70 per inch were used. These were trained professional observers, most of them doing double star work, and using excellent equipment.

"In my own work with a six-inch f10 reflector, I find myself using powers of 30 and 44 diameters per inch consistently for close double stars and for Mars and Saturn. For star clusters, except globulars, and on nebulae, I generally use a power of 34×, but these are not objects that require high resolving power, and the nebular and extragalactic objects cannot be resolved anyway. For globular clusters, however, where it is desired to resolve the individual stars, and where the brightness of the stars is such as to make this possible with a six-inch telescope, the higher powers are of course desirable.

"Double star observing demands training of the eye, nevertheless, power may sometimes be substituted for training. At the Stellafane convention in 1948 I tried to show several visitors a double star of one-second separation, Zeta Herculis. This was perfectly clear to me at 180 diameters (30× per inch), but my visitors could not see it. I then raised the power to 46× per inch, whereupon all those who had observational experience had no difficulty in seeing it.

"Another experience with the same six-inch telescope may be of interest with regard to Dawes' limit. Yellow or blue stars of one-second separation may readily be split when the seeing is reasonably good and the star within 45 degrees of the zenith. Alpha Capricorni, a wide double-double very low in the south even at culmination, shows four stars very readily. One of these four, of 10.5 magnitude, is itself a double, consisting of two stars of 11.2 and 11.5 magnitude, separated only 1.2 seconds. They are both yellow. This proved perhaps the most difficult object I ever attempted to separate, and was seen only with the greatest difficulty on a very good night and at a power of 46× per inch.

"At the other extreme is Gamma-Two Andromedae, the blue star of a wide yellow-blue pair. This fifth-magnitude star is itself a double, consisting of two stars, both blue, of about equal brightness at 5.4 magnitude, and separated only between .5 and .6 second. I have clearly seen this star as a double on at least three occasions, when it was near the zenith on good nights. At the same time the spurious disk of the third-magnitude yellow star Gamma-One Andromedae fell within the field of view and had an apparent diameter greater than the two blue stars together. This demonstrates the effect of brightness and color on the size of the spurious disk seen by the eye of the observer. It also shows, as Bell and others remark, that for small instruments under good conditions, and for moderately bright blue stars, the resolving power may be much better than that indicated by Dawes' limit, which would be about .77 second for a six-inch objective.

"My belief is that much of the distrust of the amateur for high powers is due to incorrect selection of eyepiece equipment. Most amateurs use Ramsden eyepieces, which not only have a small field of view and very poor eye relief, but also have considerable color aberration, which absolutely prevents sharpness at high powers. I have standardized on orthoscopic eyepieces with a 45-degree field of view, which are available at a moderate price, using the coated variety to eliminate 'ghosts' and light loss. For high powers I use an achromatic, coated Barlow lens in conjunction with an orthoscopic eyepiece of ⅝-inch focal length. The combination gives high power without ghosts, and with the same eye relief normally obtained with an orthoscopic eyepiece of this focal length. In addition, the emergent pencil of rays is larger than would be the case with an eyepiece of short focal length, say, .22-inch, which would be needed to obtain equivalent power without the Barlow lens.

"In sum it seems, from both theory and practice, that to use the maximum theoretical resolving power of an objective a power of 40 to 45 per inch of objective diameter is required, to enable the eye of the average observer to perceive that which the objective is able to resolve. In my own experience and that of professional observers as well, such high powers do serve a useful purpose in observing double stars and also Mars and Saturn. Under certain favorable conditions, small telescopes may be made to perform considerably better as regards resolving power than is indicated by Dawes' limit, although, as an average value for all types of stars, this limit probably represents a fairly accurate measure of resolving power in a well-constructed reflector used with adequate magnification."

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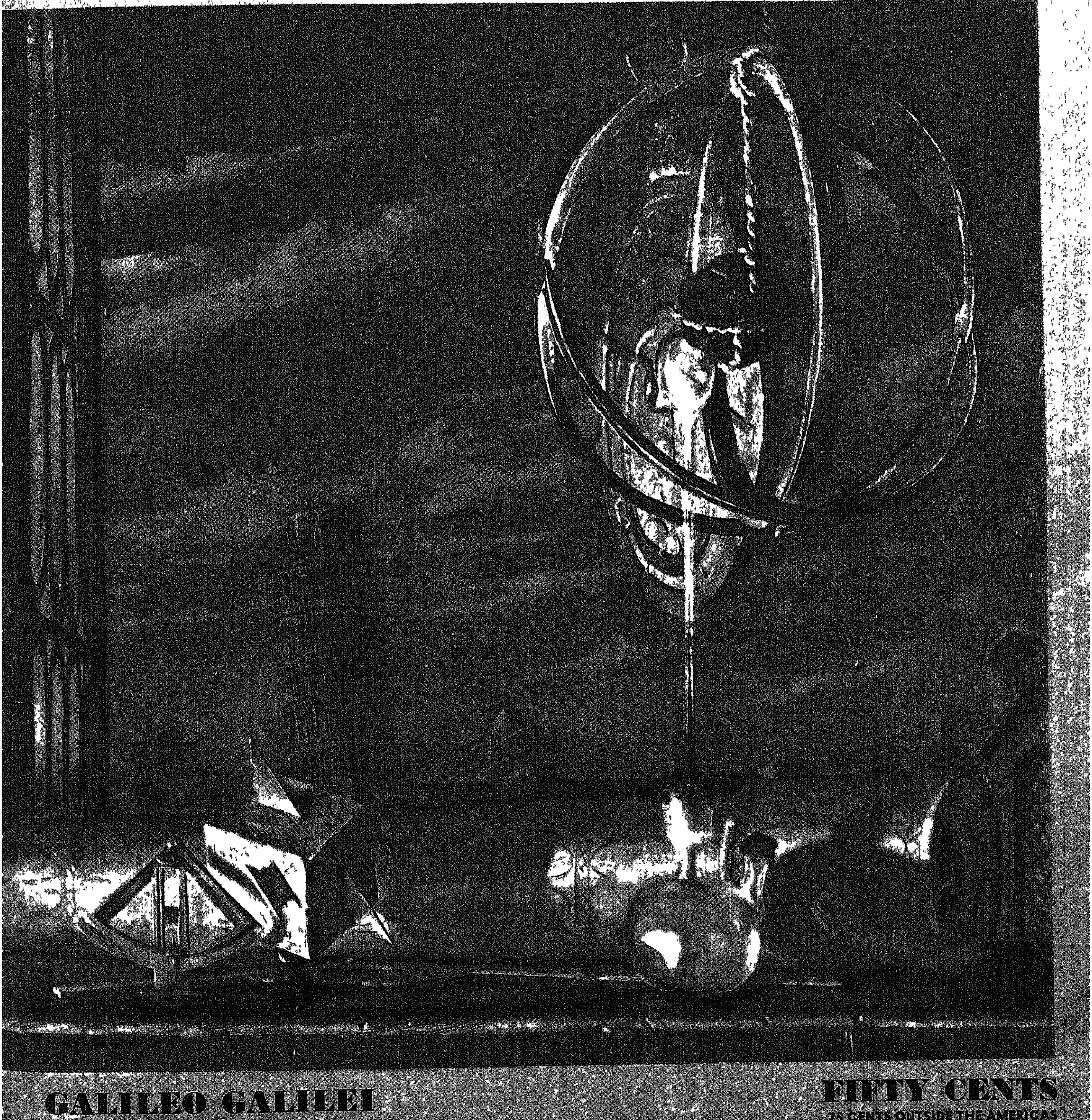
SCIENTIFIC AMERICAN



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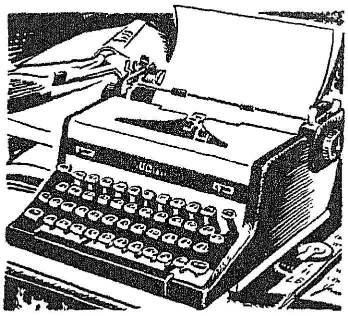

LETTERS

Sirs:

I would like to correct a minor error in the very fine article on low temperature physics in the June *Scientific American*. Mr. Davis states: "The moment we have energy, however, we are not at absolute zero. The term implies the absence of thermal energy."

It is this last statement that is not correct. The concept of absolute zero is approached in different ways in several fields of scientific study, but the ultimate definition is the same. Let me quote from W. G. Dow's *Fundamentals of Engineering Electronics:* "Absolute zero (0 degrees K.) is the temperature at which all particles, including the free electrons, have the least possible energy." A search of a reliable text on thermodynamics will reveal the same idea. Absolute zero is that state of a substance at which it has a minimum of energy, not an entire absence of energy. To go into the mathematical details of temperature scales and energy states would be beyond the scope of this letter, and, indeed, quite outside the field which *Scientific American* has set out to cover.

NORTON SAVAGE

Newark, N. J.

Sirs:

. . . In regard to the superb article on low temperature physics, I should like to add a comment for the sake of completeness. There were some scientists who *did* believe that helium 3 could easily be liquefied. Dr. C. T. Lane of Yale predicted a boiling point only .3 degrees K. too low. This prediction was based on his vapor-pressure measurements of a solution of .16 per cent helium 3 in helium 4. Dr. J. de Boer of the Van der Waals Laboratory in Amsterdam was even closer in a prediction he made based on his quantum-mechanical version of the law of corresponding states. We were pleased to find that the more optimistic predictions were also more correct.

S. G. SYDORIAK

Los Alamos Scientific Laboratory
Los Alamos, N. M.

• In his article "Low Temperature Physics" Harry M. Davis mentioned the prediction by Laszlo Tisza of the Massachusetts Institute of Technology and Fritz London of Duke University that the light isotope of helium could not be liquefied. It is this passage that Dr. Sydoriak has amplified in his letter. Dr. Sydoriak, E. R. Grilly and E. F. Hammel later showed at Los Alamos that helium 3 could indeed be liquefied.

Sirs:

On January 15, 1946, Albert G Ingalls, who conducts your department "The Amateur Astronomer," wrote me about the telescope my son John R. Pellam erected on the roof of our home here in Newark. Perhaps Mr. Ingalls will remember that his letter was addressed to either John or myself. He doubted if it would be delivered because his latest contact with John had been in November, 1932. At that time Mr. Ingalls had published photographs of the housetop installation, which is still in place.

The object of this letter is to make a comment about the article "Low Temperature Physics" published in your fine issue of June. In the first paragraph, and again on page 34, J. R. Pellam is mentioned. This is the same boy Mr. Ingalls used to be so much interested in. He is now a Ph.D., and making considerable progress in this interesting low temperature study.

GEORGE E. PELLAM

Newark, N. Y.

Sirs:

I want to tell you how pleased I am with the article "Trapped Light" which covered some of our work at the U.S. Naval Ordnance Testing Station. I want to mention only that the name of one of my associates in connection with this experiment somehow got overlooked. He is Dr. W. M. Cady, head of the Physics Division of the Research Department of the U.S. Naval Ordnance Testing Station, Pasadena Annex. The actual physical setup was developed from one of his suggestions in response to a query from a photographer who had become interested in the Kerr cell as a modulator or light-chopper. It is always personally pleasing to me to find individual credit given to people involved in a group effort, and this experiment involved the cooperative effort of many people.

A M. ZAREM

Stanford Research Institute
Los Angeles, Calif.

Sirs:

The article "Aureomycin" in your April issue carries so much interesting and valuable information that for the sake of scientific accuracy it seems desirable to point out the following: Is not the illustration on page 19, purporting to show the relative activity of the three antibiotics, incorrectly interpreted? Neither the concentrations of the antibiotics nor the diffusional rates are indicated, nor are they in fact capable of being equated when the parent molds are used. As stated by Selman A. Waksman in his *Microbial Antagonisms and Antibiotic Substances:* "The rate of diffusion of the antibiotic is parallel to its concentration"; and "the method [agar-diffusion method of measuring antibiotic activity] cannot be used for comparing different substances, but is limited to the measurement of activity of only one type of substance. With the growing molds, as sources of the antibiotics, these limitations would certainly be much greater.

ERNEST S. REYNOLDS

University of Miami
Miami, Fla.

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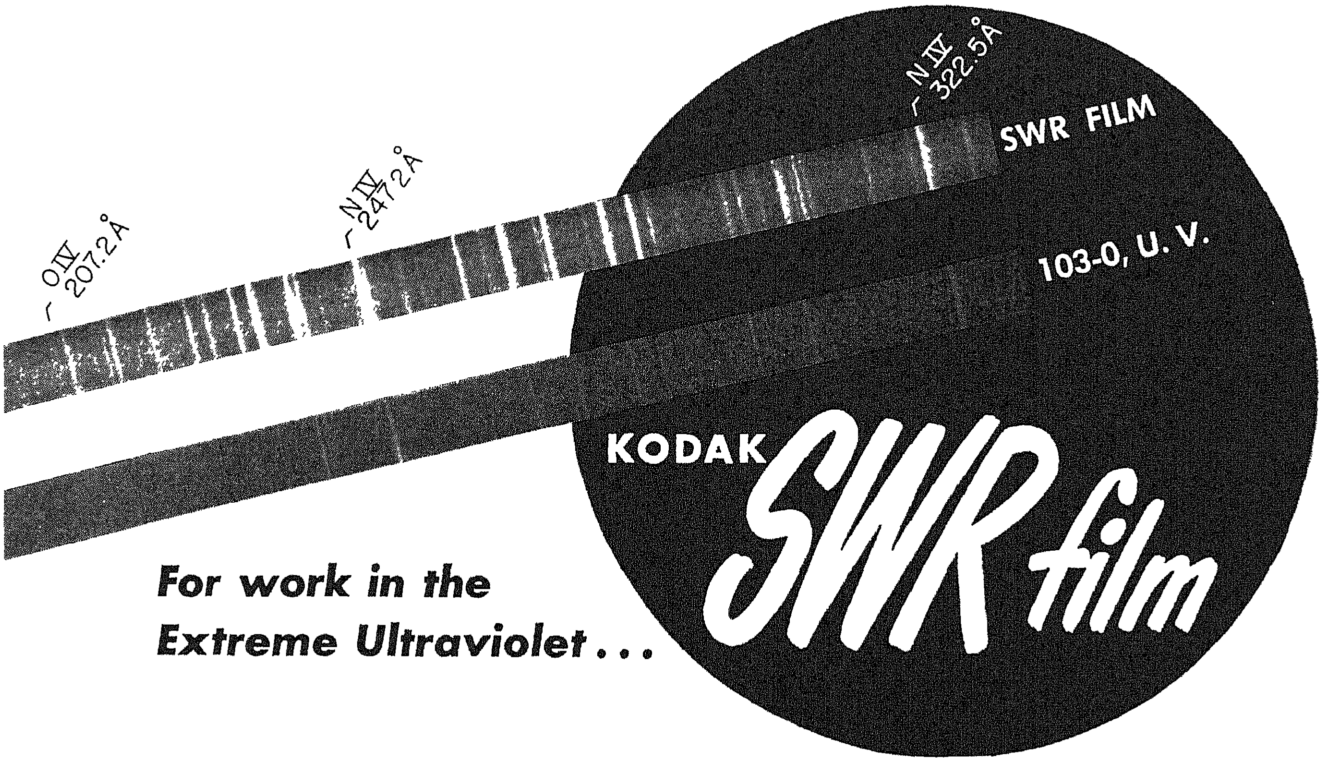

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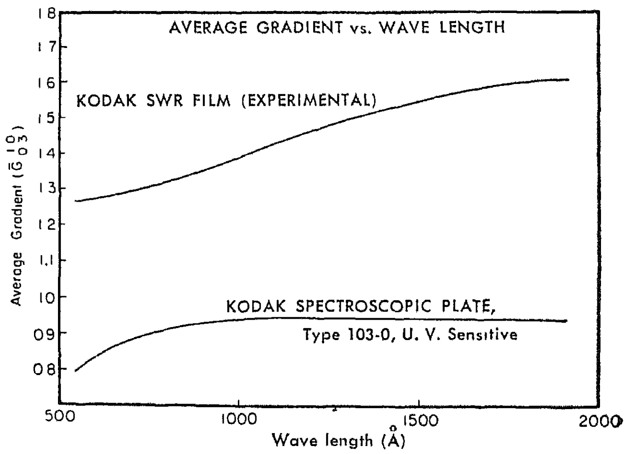

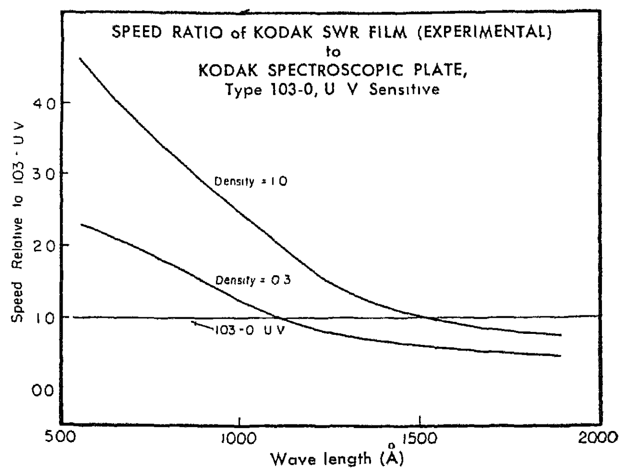

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50 AND 100 YEARS AGO

AUGUST 1899. "Lord Kelvin is to resign the chair of Natural Philosophy in Glasgow University, which he has held for so many years with such honor to the University."

"At present the medical world seems to be of the opinion that the specific bacillus of yellow fever has not been satisfactorily identified, notwithstanding the announcement that Dr. Sanarelli has segregated the germ of yellow fever. Surgeon-General Sternberg of the United States army has isolated the bacillus, which he terms for convenience 'bacillus X.' It is not claimed that this is the specific germ of yellow fever, but only one which is worthy of closer study."

"The German Minister of War recently stated that the military authorities were following the development of the automobile industry with the greatest attention and would do everything to further and make use of it. The general introduction of automobiles would increase the mobility of an army fourfold. In modern warfare the more the army can get rid of living creatures, man or beast, which are not combatants, and replace them by mechanical substitutes, the more confidently will a general take the field."

"At last the question of the Nobel prizes has been finally decided and definite arrangements have been made. After settling up the estate, it was found that the amount available for prizes exceeds $7,500,000. The prizes to be distributed are given annually for discoveries and inventions in physics, chemistry, medicine, and also for the most meritorious work in literature. The fifth prize is to be awarded to the person who has done the best work for advancing the fraternization of nations and for diminishing armies and for the propagation of peace. Each of the five prizes will amount to about $40,000. The first distribution will take place in December, 1901, and the annual date for such distribution is to be the 10th of December, the anniversary of the death of Alfred Nobel."

"In the death of Robert Bunsen science has suffered a most severe blow. He was almost the last of the great men who have made modern science what it is to-day. His long and useful life was filled with the most splendid achievements in many sciences. In collaboration with Kirchoff, he practically created three special branches of science, spectroscopy as a department of optics, spectroscopic astronomy, and spectroscopic chemistry, and we can even foretell with considerable accuracy, by means of his devices, the discovery of new elements He died on August 16 at his home at Heidelberg, Germany."

"At a meeting held recently by the Geographical Society of Berlin, under the presidence of Herr von Richthopen, the question of an Antarctic expedition was considered. From a geographical point of view, the fundamental problem as to the existence of an Antarctic continent has not yet been solved, and besides this there are other questions for which a solution is desired, such as the geological structure and character of the Antarctic soil, this being of importance owing to the relation supposed to have existed between South America and Australia. Among other questions are the study of masses of ice and their movements, the origin of cold oceanic currents, the condition of atmospheric pressure and temperature in those regions, besides the questions relating to terrestrial magnetism, etc."

AUGUST 1849. "The Reports of the Cholera published from day to day in this city, have been so different from the weekly Reports of our city Inspector that we have concluded not to publish them any more, for no dependence whatever can be placed in them. The Report of the City Inspector makes out the number of deaths to be much larger than the Board of Health Reports. In the last week's Reports there are 57 of a decrease as compared with the preceding week. The whole number of deaths last week was 1,352: of these 692 were from Cholera."

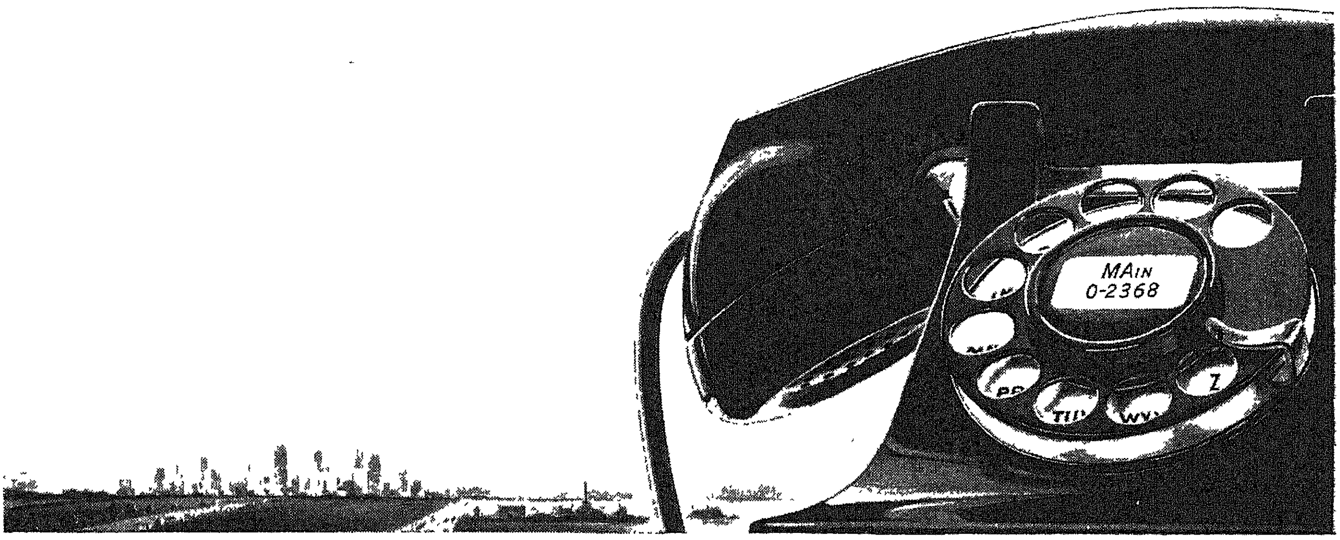
"The increasing temperature, found at increased depths in digging the Artesian wells, more particularly that of Grenelle in France, has been adduced by M. Arago, and other philosophers as proof of central fires in the earth. Commander C. Morten, known as the propounder of the 'electrical origin of hailstones,' merely regards the increased temperature at increased depths as the natural consequence of increased pressure of the atmosphere, and as much a matter of course as the increased cold or diminished temperature found to exist on ascending mountains according as the atmospheric pressure diminishes in the ascent."

"Mr. Lyell states that if we can suppose a mass of sandstone a mile in thickness to have its temperature raised 200 degrees Fahrenheit, it would lift a superincumbent layer of rock to the height of ten feet. Calculations have been made by geologists which appear to account for the elevation of land in Sweden by a rise of only three degrees temperature, (Réaumur), supposing the stratum to be 140,000 feet thick. Upon a similar supposition, the rise and fall of the waters of the Caspian Sea might be explained."

"Two origins are now ascribed to limestone—one, that of chemical precipitation; the other, to the labors of the infusoria. There can be no doubt that many of the enormous beds of this substance with which we are familiar, are the results of the accumulation of innumerable millions of these tiny creatures. They swarm in all waters, indifferently in salt as in fresh, and secreting from the lime held in solution by such water the necessary material for their enormous aggregation, create, in process of time, the vast strata of which we speak. The Great Pyramid of Egypt has been looked upon by men as a miracle of human power and skill, yet every stone in its composition is a greater far, for the limestone of which the vast structure is built was erected long ago by an army of humble animalcules more numerous than all the hosts of a thousand Pharaohs."

"The city of Milwaukie, Wisconsin, has now a population of 16,000. In 1835, it possessed only one white inhabitant."

"The American Association for the Advancement of Science, commenced its second annual meeting, at Harvard Hall, Cambridge, (Mass.) on Tuesday of last week. Professor Henry was elected President for the current year. The first paper read, was from Professor Secchi of Georgetown, relative to the causes of the Aurora Borealis. He propounded a theory based upon the powers of moist air as a conductor of Electricity, and gave much information on the subject."



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Bell Telephone Laboratories lead the world in improving communication devices and techniques.

Western Electric Company provides the Bell operating companies with telephone equipment of the highest quality at reasonable prices, and can always be counted on in emergencies to deliver the goods whenever and wherever needed.

The operating telephone companies and the parent company work together so that improvements in one place may spread quickly to others. Because all units of the System have the same service goals, great benefits flow to the public.

Similarly, the financial good health of the Bell System over a period of many years has been to the advantage of the public no less than the stockholders and employees.

It is equally essential and in the public interest that telephone rates and earnings now and in the future be adequate to continue to pay good wages, protect the billions of dollars of savings invested in the System, and attract the new capital needed to meet the service opportunities and responsibilities ahead.

There is a tremendous amount of work to be done in the near future and the System's technical and human resources to do it have never been better. Our physical equipment is the best in history, though still heavily loaded, and we have many new and improved facilities to incorporate in the plant. Employees are competent and courteous. The long-standing Bell System policy of making promotions from the ranks assures the continuing vigor of the organization.

With these assets, with the traditional spirit of service to get the message through, and with confidence that the American people understand the need for maintaining on a sound financial basis the essential public services performed by the Bell System, we look forward to providing a service better and more valuable in the future than at any time in the past. We pledge our utmost efforts to that end.

LEROY A. WILSON, *President*
American Telephone and Telegraph Company.
(From the 1948 Annual Report.)

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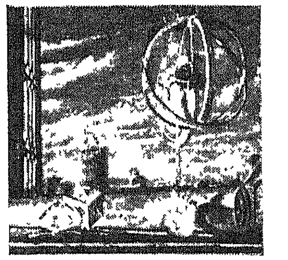

THE COVER

The painting on the cover is an imagined still life and landscape set in the Italian city of Pisa during the lifetime of Galileo Galilei (*see page 40*). Across the window sill in the foreground lies one of the many telescopes made by Galileo Lying flat in front of it is a proportional compass, another of Galileo's inventions To the left are a plane level and a cubical sundial. The bottle of pink fluid at the right is Galileo's "thermoscope." Hanging above it is an armillary sphere, a contemporary device that was used to represent the positions of celestial objects. In the center of the armillary sphere hangs a lodestone. Behind it hangs an Italian astrolabe made in 1588, when Galileo was 24 years old. In the background is the famous Leaning Tower, from which, contrary to legend, there is little reason to believe that Galileo ever dropped two objects of unequal weight. The objects in the foreground are from the Smith Collection in the Low Memorial Library of Columbia University.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
12-15	David Stone Martin
17-21	Irving Geis
22-23	*The Illustrated London News*
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40-43	The Burndy Library
44	The Pierpont Morgan Library (*top*), The Burndy Library (*bottom*)
45	The Burndy Library
47	The Harvard University Library
49-51	Eric Mose
53-55	Ralph M. Evans
57	*Human Behavior and the Principle of Least Effort*
58	David Stone Martin
60	H. P. Wilkins
62-63	Joseph F. Odenbach

What GENERAL ELECTRIC People Are Saying

SAUL DUSHMAN,

Retired Assistant Director, Research Laboratory

THE VACUUM: Although the vacuum was little more than a scientific curiosity for ages, during the past two decades the art of producing and maintaining high vacuums has become an industrial process of great importance. To realize this, you need only consider the radio industry; it depends for its very existence on the use of vacuum processes in turning out the extremely diversified range of electron tubes —from the little ones used in your radio receiving set to the mighty 100-kilowatt tubes used by the large broadcasting stations. All of these must be evacuated to the highest degree obtainable.

G.E. Monogram, July-August, 1949

★

I. F. KINNARD

Manager of Engineering, Meter & Instrument Divisions

CURRENT TRANSFORMERS: During more than 50 years of continuous manufacture, it has been almost universal practice to insulate dry-type instrument transformers by wrapping a fibrous material—commonly varnished cambric or crepe paper—around the transformer coils and then impregnating this matrix with asphalt or a similar insulating compound. In many designs as much as one-quarter mile of crepe paper has been wrapped on the coils for proper insulation. Because of the complex configuration of the coils, most of this wrapping has been done by hand. It has, therefore, long been the goal of instrument-transformer engineers to develop a method of molding or casting an insulating material around the transformer core and coils, thus eliminating the necessity for hand wrapping.

After considerable experimentation such a method, as well as a material suitable for use with the method, has been developed through the joint efforts of several divisions within the General Electric Company. The result is . . . a transformer of unit construction, with all the component parts firmly molded together in a continuous casing of butyl. . . . Its performance characteristics represent a distinct improvement over older designs of transformers and are due in large measure to the excellent properties of butyl and to the new concept of molded transformer insulation.

General Electric Review, June, 1949

★

C. G. BACON

General Engineering & Consulting Laboratory

CORROSION: Practically all chemical elements can now be made radioactive and in considerable quantities. For instance, a one-hundred-gram lot of radioactive iron can now be obtained at a nominal cost. Chemical combinations and processes having iron or other elements as constituents can now be studied by substituting radioactive for normal iron and following the course of the element through the action with suitable radiation-detection methods. Similarly such reactions as take place in steel and gasoline refining, metallurgy, corrosion, and other processes may be studied in this manner.

An attack on the problem of corrosion by the application of radioactive tracers obtained from Oak Ridge is being made in the General Engineering & Consulting Laboratory. Radioactive iron is used. . . .

General Electric Review, May, 1949

★

R. C. SOGGE

Manager, Standards Division

STANDARDS: The terms "standards" and "standardization" have very broad meanings and have a general application, so that we come in contact with some form of standards almost daily in our personal activities as well as our business. One place where we frequently hear of standardization is in connection with mass production. The production of goods in large quantities makes it important that the products and parts be readily interchangeable. Experience has shown that one of the most effective ways of bringing this about is through proper standardization. . . .

In general, standards are good because they aid in the simplification of manufacture, conserve material and labor, help to attain lowest cost, increase output per unit of floor space, shorten production time, reduce inventory. Standards also promote a clearer understanding between buyers and sellers, and a whole group of standards promotes safety to employees of manufacturing companies and to the public. . . . Practically all standards contribute in one way or another to a lower cost of doing business. I think we might say that we pay for standards whether we use them or not, because we forego savings when we fail to use them.

National Electric Manufacturers Assn., San Francisco, May 16, 1949

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CONTENTS FOR AUGUST 1949   VOLUME 181, NUMBER 2

ARTICLES

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SCIENTIFIC AMERICAN

AUGUST 1949 VOL. 181, NO. 2

THE PERSONALITY OF PEOPLES

With the aid of depth psychology, anthropologists are learning much about how a nation's cultural patterns may shape the character of its citizens

by Ralph Linton

THE idea that human groups differ in personality, which found a *reductio ad absurdum* in the Nazi philosophy, is not, of course, peculiar to our time. Herodotus discoursed on the temperamental differences among the ancient Greeks, Egyptians and Persians. Julius Caesar and Tacitus gave us thumbnail sketches of the psychology of the Celts and Germans. In all ages social philosophers have taken psychological differences among peoples for granted and have tried to account for them. And there has always been a host of less judicious or less scrupulous writers who have used the idea for self-congratulation or for the vilification of foreigners.

It would be hard to find a subject of continuing discussion that has been attended by more heat and by less concrete evidence. Only within the last 30 years, as certain phases of anthropology and psychology have developed, has it become possible to define the problems involved and to attack them directly. The first step has been to obtain a clearer definition of the human groups with which the investigator has to deal. Two sorts of groupings are obvious and easily recognizable: races and societies. Race is indicated by the individual's physical type. Membership in a society depends upon association and training and is indicated by the individual's behavior, the particular culture to whose patterns he adheres. Members of a particular racial group may be scattered through many societies while, conversely, a single society may include members of several different races.

To understand the relations between these two groupings, it is necessary to have a clear picture of what is meant by the term "race." It is, unfortunately, a very general term, applied indiscriminately to groups whose members show widely differing degrees of physical resemblance. For scientific purposes it is more precise to classify people by (1) breed, (2) type and (3) stock.

A breed is a homogeneous human group, usually small, whose members resemble one another so closely that it can be assumed that all of them have a common ancestry in the not too distant past. This grouping corresponds to a breed of domestic animal, say the Irish terrier. A type is composed of a number of breeds which, though differing in minor respects, have many characteristics in common. It corresponds roughly to such a group as rough-haired terriers. A stock is composed of a number of breeds and types and is analogous to the more inclusive grouping, terriers.

In the human species there has been so much mixing that today even moderately pure breeds are found only in culturally backward areas where outside contacts are infrequent. There are many types, however; examples are the Nordic, Alpine and Mediterranean types in Europe. All the European types, plus a number of others scattered through Asia and Oceania, together compose the Caucasic stock. This is popularly known as the White Race, although some of the types assigned to it are actually darker than the average American Negro.

Occasionally, among isolated "primitive" peoples, a breed may coincide with a society, but in general the racial and social divisions cut across each other. Every known type and stock has representatives in several societies, and every civilized society, *i.e.*, nationality, includes members of several breeds and types. Thus every European nationality includes Nordic, Alpine and Mediterranean types with all sorts of mixtures. Various nations differ in the percentages of each type relative to the total population, but in no nation is a single type strongly dominant. Nor does the type have any significance as an indicator of social status, for representatives of all types are found at all levels of society. This means that for the average European or North American, the Caucasic type differences are of only academic interest.

THE situation with respect to stock differences is quite otherwise. While most of us never notice whether a neighbor is Alpine or Mediterranean, all of us are keenly conscious of whether he is Negroid or Mongoloid. The white dominance of the world during the past two centuries has sensitized us to the physical differences that serve as criteria for these groupings. At the same time, an uneasy conscience has made us eager to prove that white dominance rests on

CARE OF CHILDREN in various societies is illustrated in these drawings. Beginning at left they show successively the typical disposition of infants among the people of Alor (in Dutch East Indies), in Japan, in New

something more enduring than superior technology and military skill. In recent times the search has concentrated on racial psychology, increasingly implemented by modern testing techniques.

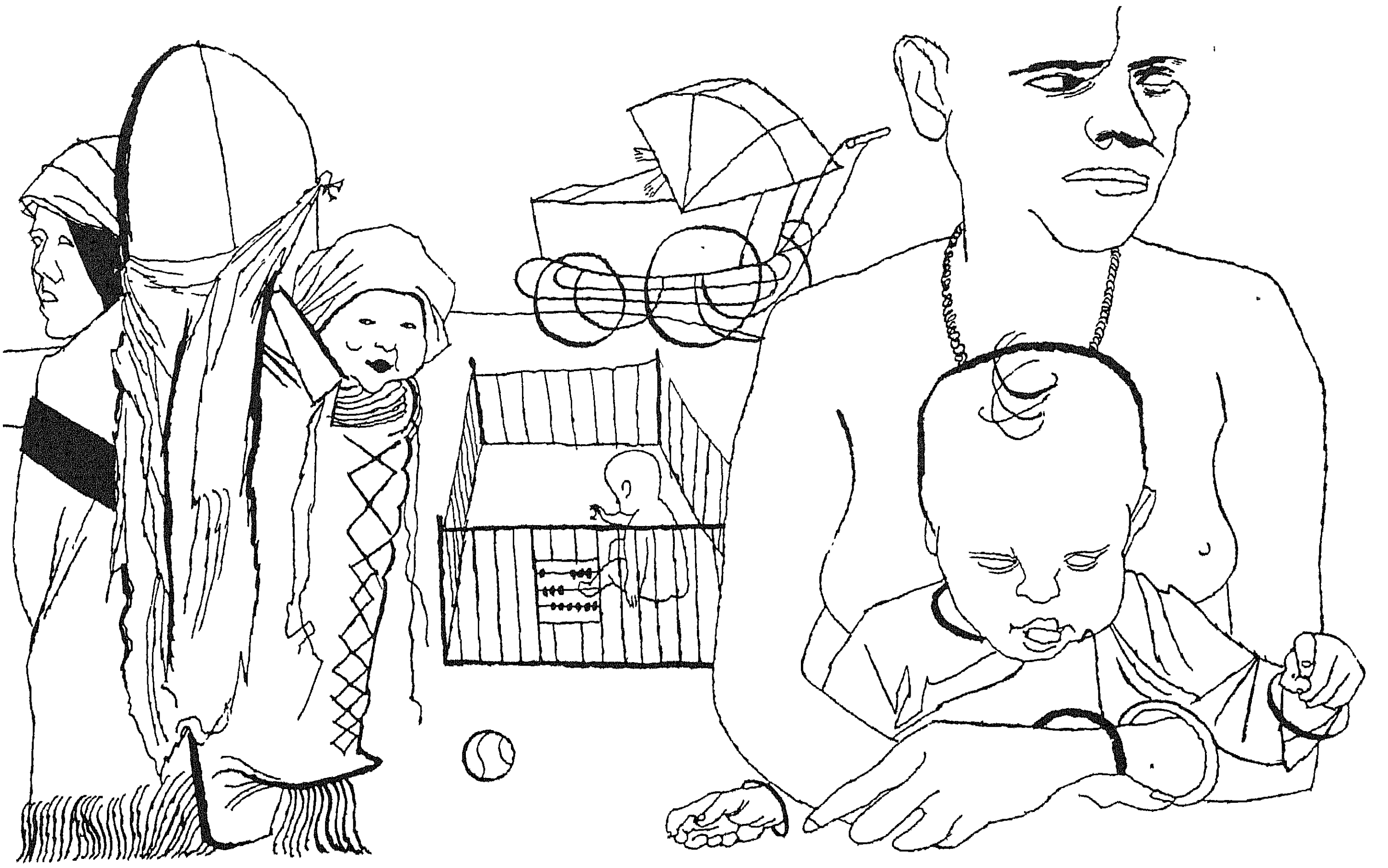
Very little of this work has been done with human breeds, where inherited psychological characteristics should be most obvious. Most of the studies have tried to determine differences between types or even stocks. They have relied mainly on tests for special abilities and particularly I.Q. A few attempts have been made to compare racial personality on the basis of Rorschach and Thematic Apperception tests.

Although the literature dealing with such studies is voluminous and often controversial, most authorities agree that the existence of significant racial differences has never been proved. On the basis of the evidence it seems most improbable. Indeed, we now know enough about the processes of personality formation to make it seem unlikely that a specific kind of personality can be inherited. An individual's psychological potentialities, which presumably are determined by biological factors, may be influenced by heredity. His personality, on the other hand, is a result of the interaction of these potentialities with his environment. In this interaction his inherited potentialities may not be the principal factor. Thus a child with an I.Q. of 100 might be either the brightest or the dullest member of his family group, depending on accident of birth. Whichever he was would have much more influence on his experiences with other people and on his resulting personality characteristics than would his I.Q. level in itself.

THE finding that races do not differ significantly in inherited psychological potentialities has been hailed with enthusiasm by the anti-racists and must be welcomed by all men of good will. At the same time, the layman is likely to feel that the findings contradict common sense. Whatever the results of psychological tests, experience tells him that the average Swede and the average Italian act differently and even seem to think differently most of the time. This, however, is because Swedes and Italians belong to different societies and have been brought up in different cultures. Both are members of the same Caucasic stock and many individuals in both groups belong to the same racial types. Thus if either overt behavior or personality were determined by race we might expect to find them much more alike than they actually are.

That the behavior of people in different societies does differ is obvious to anyone who has visited a foreign country. Yet most of this behavior has been learned quite objectively and can be learned by any outsider. An American in China soon becomes reasonably expert with chopsticks—though it may be a few months before he can cope with a poached egg. The native scholar whose tribal language has no word for any number larger than three can learn to recite the multiplication table in English. Moreover, he can understand mathematical principles when they are taught to him, and can learn to solve problems. The acquisition of such skills need not mean any change in the attitudes, values and emotional responses of the individual. The different behavior norms for different societies, various as they are, still leave a possibility that the apparent personality differences in the people themselves are no more than muscle-deep.

As men of good will, all scientists who have worked on problems of personality and culture would be delighted to find proof that the members of all societies as well as all races are really alike. If such were the case, it would be easy for all peoples in the world to get along together, once the differences in their superficial habits had been recognized and discounted. Most anthropologists with field experience are prejudiced in favor of such a view when they begin per-



Guinea, among American Indians, in modern U.S. and in Malaya. The Alorese virtually ignore their children; at the other extreme of child care the Japanese tend to make them the petted center of the family's attention.

sonality studies. If one lives intimately with another society for any length of time, he becomes more conscious of individual than of group differences. The longer he lives with "primitives," the more they stand out as distinct human beings who remind him of particular people he has known at home. It is only in recent years that it has become possible to replace such informal judgments and wishful thinking with the results of genuine research.

The study of group differences in personality and their causes is fraught with great difficulty. The extent to which societies can be subjected to controlled experiment is strictly limited, and the factors involved in uncontrolled social situations are too complex to yield to mathematical treatment. In the study of personality in particular, it is impossible for the investigator to reproduce in the laboratory the numerous and long-continued influences which shape the growing child. He can only observe children at different age levels and in different family situations, obtain life histories from grownups and try to deduce from such imperfect evidence whatever relation may exist between experience and personality.

In this study the work of the psychoanalysts has proved invaluable. In spite of differences in the theoretical approaches of various schools, they have been able to show fairly constant relationships between certain sorts of early experience and certain features of adult personality. Anthropologists, although more interested in societies and cultures than in individuals, have also contributed techniques. They have recognized for many years that cultures are integrated wholes, and that each culture tends to be organized about certain main activities or interests. These inevitably play a part in shaping the personalities of the individuals in the society. Thus the culture of the Plains Indians was organized around war and the highest rewards went to men who were brave and self-reliant. The techniques of child training were designed to develop these characteristics. On the other hand, the culture of the Tanala, a southeast Madagascar tribe, was organized about cooperative agriculture, and their main values were linked with the preservation of the extended family groups into which they were organized. The highest social rewards went to docile, obedient individuals with little initiative. Child training was directed toward developing these qualities, partly by strict discipline, partly by an ingenious series of compensations for the frustrations suffered.

In most societies the approved methods of child training might be expected to produce the sort of people who would find the society's culture congenial. On this point the cultural evidence and the conclusions of the psychoanalysts check each other very closely. A society's methods of child training produce attitudes which not only reinforce the existing patterns of its culture but also influence the acceptance of new patterns. The members of a society will readily accept ideas and appliances that are in line with their established attitudes and values; they will reject those which run counter to them. For example, the early missionaries in Polynesia were delighted to find that the natives took at once to hymn-singing and church socials, and kept the Sabbath with a vigor engendered by a long-standing belief in the fatal results of taboo-breaking. They were less pleased to discover that the converts could not be convinced of original sin, and regarded chastity as a serious breach of good manners.

In recent years a number of psychological tools have been added to the investigator's equipment. Projective tests such as the Rorschach have improved and multiplied and better techniques have been developed for the collection and study of life histories, analysis of dreams, and so forth. It is now possible to make a many-pronged attack on the

problems of personality and culture with a combination of anthropological and psychological techniques. The results of different techniques can be checked against one another, this feature is important because some of the techniques are still very much in the experimental stage.

The most thorough and inclusive study of this sort that has been made to date was an investigation of the people of Alor, an island in the Dutch East Indies. The investigator, Dr. Cora Du Bois, organized her ethnological material, obtained during two years in residence, around the life cycle of the individual. This was supplemented by autobiographies of 28 men and women, by children's drawings, by maze tests, by word-association tests and by Rorschach tests. The material from each test was analyzed by a different psychologist who was not informed of the conclusions reached by the other analysts. The autobiographies were studied by a psychoanalyst to determine personality patterns. The cultural material was studied by anthropological techniques to determine dominant attitudes and values. The results of all these approaches were in fairly close agreement, making it possible to establish both personality norms for the group and the presence of deviant individuals. A number of less complete studies of other societies and cultures have confirmed the validity of this method.

Although a tremendous amount of work remains to be done, certain facts about personality norms and personality formation have been established. It can be shown that all societies include a wide range of personality types. In fact, given a large enough community, it should be possible to find any sort of individual personality that has been found elsewhere. Nonetheless, the frequencies of the various types do differ enormously from one society to another. A personality pattern that is characteristic of most of the individuals in one society may be so rare in another that it is considered psychopathic.

For example, North American Indians regarded mystical ecstasies and the seeing of visions as quite normal, while in our society such experiences call for psychiatric observation. On the other hand, an aggressive, competitive personality, which is the modern American ideal, is regarded as psychopathic by many Indian tribes in which the great aim of the individual is to be completely average. It must be added that while unusual personality characteristics may place the individual at a disadvantage, this is not necessarily the case. In a society where the "normal" personality is docile and passive, as among the Pueblo Indians, a rare and atypical aggressive individual may be in a pleasant position. He can dominate and exploit his neighbors, subject only to the old adage that it is a long worm that has no turning.

ALTHOUGH no two individuals ever behave exactly the same, even in similar situations, culture sets limits to the normal range of individual variation. It is this limiting pattern to which we must look for clues about the dynamics of personality formation. The developing individual is shaped by the pattern in two ways. 1) by his experience of what other people, acting in accordance with the pattern, do to him, and 2) by what he learns from other people as a result of imitation or instruction. Cultural influences of the first sort begin to operate on the infant from the moment of birth. According to the customs of his society, he may be laid naked on a hard plank (New Caledonia), tucked into a padded cradle (Plains Indian), or tightly bandaged from the neck down (southern Europe). He may be carried about constantly (Malaya), or left alone half a day at a time (Alor). He may be fed whenever he cries (Malaya), on schedule (modern America), or simply when it suits his mother's convenience (New Guinea). He may be the petted center of the family's attention (Japan), or receive only the minimum care necessary to ensure his survival (Alor). Training to control his excretory functions may be imposed within the first six months (Madagascar), or may be delayed until he can learn by imitating his elders.

Most depth psychologists insist on the great importance of such early experiences in laying the groundwork for the developing personality. It is rarely possible, however, to show a one-to-one relationship between a particular feature of early treatment and some characteristic of the adult personality. The effects seem to derive more from the atmosphere created by the method of infant care than from any of its details. The care may be warm and affectionate or coldly indifferent, encouraging or repressive. Whatever the atmosphere, the child derives from it his earliest and most generalized picture of the universe in which he finds himself. This is also his most enduring picture; it survives in the depths of his mind below all later acquired ideas and behavior patterns. It influences his anticipations, his appraisal of new situations and—most important of all—his appraisal of himself as adequate or inadequate, secure or insecure, loved or rejected.

The results of such early experience are buried but never obliterated. They linger on at the subconscious level and are responsible for all sorts of reactions which people can recognize as irrational, even in themselves. The child who has been bullied by his father will always expect people in authority to bully him; even a mild and necessary exercise of power will make him cringe or infuriate him. A child who has been ignored will not only expect to be ignored in later life, but will be unable to respond to friendly advances. A child brought up in a family where numerous men and women care for him like parents (a situation found in many parts of Polynesia) develops a personality quite different from the American norm. He is self-confident and pleasant, but has no ability to focus emotions. Since no single person is ever continuously responsible for rewarding or frustrating him, he never learns to love or hate wholeheartedly. His attitude, when he parts with a friend or wife, is "Oh well, another will be along presently."

Most of these are unintended effects of culture. In addition, every society tries to shape its members directly and consciously. As soon as a child is old enough to understand speech, people begin telling him what to do and pointing out other people's behavior as something to be imitated or avoided. Apparently children learn to learn and to imitate very much as they acquire other skills, and for the same reason—it pays. Most of the things that can happen to people in any society have already happened a good many times, and the society has worked out ways of dealing with them. It is both simpler and more rewarding to learn these ways, *i.e.*, the society's culture patterns, than to try to work out new solutions for oneself. Except in societies whose cultures are undergoing rapid change, such as our own, most people can lead pleasant and effective lives simply by learning without thinking.

HOW far these later learnings affect the deeper levels of the personality is the most important problem now confronting students of personality and culture. It is a well-known principle of psychology that behavior which is successful, *i.e.*, rewarded, is thereby reinforced. This is the basis of habit formation. It is also an observed fact that most of the patterns of overt behavior which go to make up the culture of any society reflect attitudes and anticipations, frequently unconscious, which are shared by most of the society's members. We cannot say positively that the patterns of overt behavior, by their success in action, reinforce the deeper psychological patterns which they reflect, but it seems likely that they do.

Up to this point we stand on fairly firm ground, but there is another side to the picture which may be of even greater practical significance. In individual learning, those responses that are punished or simply not rewarded are extinguished. This also holds for culture patterns on the level of overt behavior. The Plains Indians stopped going to war when the U.S. Army became too strong for them. They stopped hunting for buffalo when there were no more buffalo.

So the ultimate question is this: Is it possible, by extinguishing some of the patterns of a culture and substituting others, to bring about a lasting change in the society's personality norms? The individual attitudes from which these norms are derived begin to be established long before conscious instruction can get under way. Under normal cultural conditions, the norms are reinforced by instruction and by the individual's later experience as a member of society. The problem is whether they can be extinguished by similar means. Failing that, how far can they be modified and, in either case, what techniques are most likely to prove effective?

This is a vital problem for a changing world. If education can reach the deeper levels of personality, the personality norms of society can be changed consciously and purposefully. If these levels cannot be reached after early childhood, the outlook is much less promising, in fact well-nigh hopeless. The early experiences that shape an infant's personality derive not only from cultural patterns but also from the sort of people who apply them. To change personality norms at this level, it would be necessary to restaff most nurseries.

The personality norms of most societies have shown a continuity through time that is highly depressing to those who labor in the cause of sweetness and light. Moreover, most widely publicized attempts to change national character have not been particularly successful. The Russian Brave New World seems strangely familiar to one who knows that country's history. The Nazi experiment seems to have been less an attempt at fundamental change than a shift in emphasis among psychological patterns already well established. The Fascist attempts of various Latin countries have reflected their varying personality norms with striking fidelity.

However, none of this is conclusive and the outlook is not as dark as it seems. Side by side with such attempts to impose change from above, there have been other attempts which corresponded to a real united will for change—and which have been successful. These changes can be traced in the rise and stabilization of various religious sects, and it is here that we are most likely to find the knowledge which will enable us to develop effective techniques for reshaping personality norms. In a time when change in certain aspects of "human nature" has become necessary to the survival of our species, it is comforting to know that it can be done and has been done. The problem of the scientist is to find out how.

Ralph Linton, Sterling Professor of Anthropology at Yale University, is the author of The Cultural Background of Personality.

CONTRAST IN CHARACTER that is produced by the basic differences in attitudes of two tribes is typified here in contrasting Indian dress. The Zuñi Indians (*left*) were a passive group. The Comanche (*right*), whose culture was built around war, developed belligerence as a personality norm.

POTASSIUM

The 19th element of the periodic table has fascinating physical and biological eccentricities. Its behavior in cells is one of the fundamental characteristics of life

by Wallace O. Fenn

A NORMAL human adult has enough potassium in his body to kill 100 people if it were injected into their blood, yet if he got no potassium in his diet he would soon be paralyzed and die. The element is remarkable in many ways. Although it is an inorganic substance, it influences so many biological processes that it must be considered a basic stuff of life. On the other hand, potassium is as intriguing to geologists and physicists as it is to biologists. As a naturally radioactive element, it has played a key role in the geological history of the earth. Its physical and chemical properties are peculiar and in some respects unique. Indeed, potassium is coming to be recognized by biologists as one of the most interesting and significant among all the 92 natural elements.

Until recently the element was of interest chiefly as an ingredient of fertilizers and industrial potash. It derived its chemical symbol, K, from the German *kalium*, meaning "pot-ashes," and its English name is a modification of the translated term. But it had been used a good while before it had a name. The Romans knew that a soft soap could be made from wood ashes. Potassium was the basis of one of the first industries established in the New World: the Jamestown colony began to ship wood ashes to Europe in 1608. The element's importance as a plant food was not discovered, however, until 1840, when the German chemist Justus von Liebig found that the "bitter salts" being thrown away at German salt mines were an excellent fertilizer. Today most of the potassium sold is used for this purpose. Rich deposits of sylvite, or potassium salt (KCl), were found in 1931 in New Mexico at a depth of 962 feet, in the underground bed of what was probably an ancient, dried-up lagoon.

The first to isolate the element itself (in 1807) was the chemist-poet Sir Humphry Davy. Pure potassium is a soft, bluish-silvery metal—one of the series of alkali metals that includes lithium, sodium and rubidium. Each element in this series of the periodic table has only one electron in its outermost shell. The single electron is easily lost to another atom, so these elements generally carry a positive charge, and they are very active chemically. The importance of potassium to plant and animal life lies in the fact that it is the dominant positively-charged substance in protoplasm. One of the remarkable facts about potassium is that, although it is a close chemical relative of sodium, being next above that element in the alkali series, its chemical behavior is very different. In living organisms potassium and sodium sometimes show directly opposing effects, and potassium cannot be replaced by sodium.

Before we go into the biological role of potassium, we need to consider some of the physical peculiarities of the element. Its outstanding eccentricity is that it is the lightest element with a naturally radioactive isotope; in fact, in the whole lower third of the periodic table this is the only substance that is radioactive in nature. Potassium, whose atomic number is 19, has six known isotopes. Three of them (K-38, K-42 and K-43) are artificial, unstable, short-lived freaks created by bombarding potassium or other atoms with high-speed deuterons or alpha particles. The natural element is made up of the isotopes K-39, K-40 and K-41. Of these K-39 and K-41 are stable and account for nearly 93.4 per cent and 6.6 per cent, respectively, of all natural potassium. The natural radioactive isotope is K-40, a very long-lived species with a half-life of 1.3 billion years. K-40, now in the last stages of radioactive decay, survives today as only .012 per cent of natural potassium, and its significance is dwindling away to nothing. It was undoubtedly of great importance, however, in the early history of the earth's crust. Making reasonable assumptions about the rate of decay and early abundance of K-40 and the energy given off by its radioactive disintegration, it can be calculated that the heat produced would have been great enough to keep the earth in a molten state. It appears highly probable that the decline of K-40 through radioactive decay was an important factor in the hardening of the earth's crust.

In general, isotopes with an even number of neutrons are stable, and those with an odd number unstable. K-40 has 19 protons and 21 neutrons, so it decays to an element with an even number of neutrons. But here again potassium's behavior is peculiar. K-40 can decay in two different ways, by emitting an electron or by capturing one. It is as if the atom could not decide whether it had too many neutrons for its protons or too many protons for its neutrons. Usually it sheds a beta particle (electron), thereby converting one of its neutrons into a proton, and is transformed into calcium 40. But about one atom in seven reverses the process: it picks up an electron from its inner electronic shell, the so-called K shell. The electron neutralizes one of its protons, and the atom drops to the next lower atomic number, becoming argon 40. Apparently K-40 can also discharge a positron from its nucleus with the same result. Since most of the K-40 disintegrates to calcium, it is a plausible assumption that all of the calcium which is now on the earth was originally present as potassium.

There is one further interesting fact to be noted about the element. It is much less abundant than sodium in ocean water, but more abundant than sodium in sedimentary rocks. Certain evidence suggests that living cells are at least partly responsible for the extensive removal of potassium from the oceans. Marine or-

ganisms may have produced this result by absorbing potassium into their cells in preference to sodium. When they died they sank to the sediment on the bottom, taking the potassium with them.

POTASSIUM is taken from the soil by the roots of plants. Each crop removes 20 to 150 pounds of potassium per acre. But the insolubility of potassium compounds in the soil makes a very large fraction of the total potassium of the soil unavailable for plant use. It is only the exchangeable potassium, that fraction which can be washed out by exchange with other positively-charged ions such as ammonium or hydrogen, that is available for plants. Thus the plant root in relation to potassium is like a man on a life raft with only a mouthful of rain water. Except for his meager supply there is "water, water everywhere, nor any drop to drink." This analogy emphasizes in an exaggerated manner the scarcity of the soluble relative to the insoluble potassium. For the growing of crops, the 20 to 150 pounds per acre taken as plant food and the 10 to 15 pounds per acre lost by leaching should be replaced by fertilizer each year.

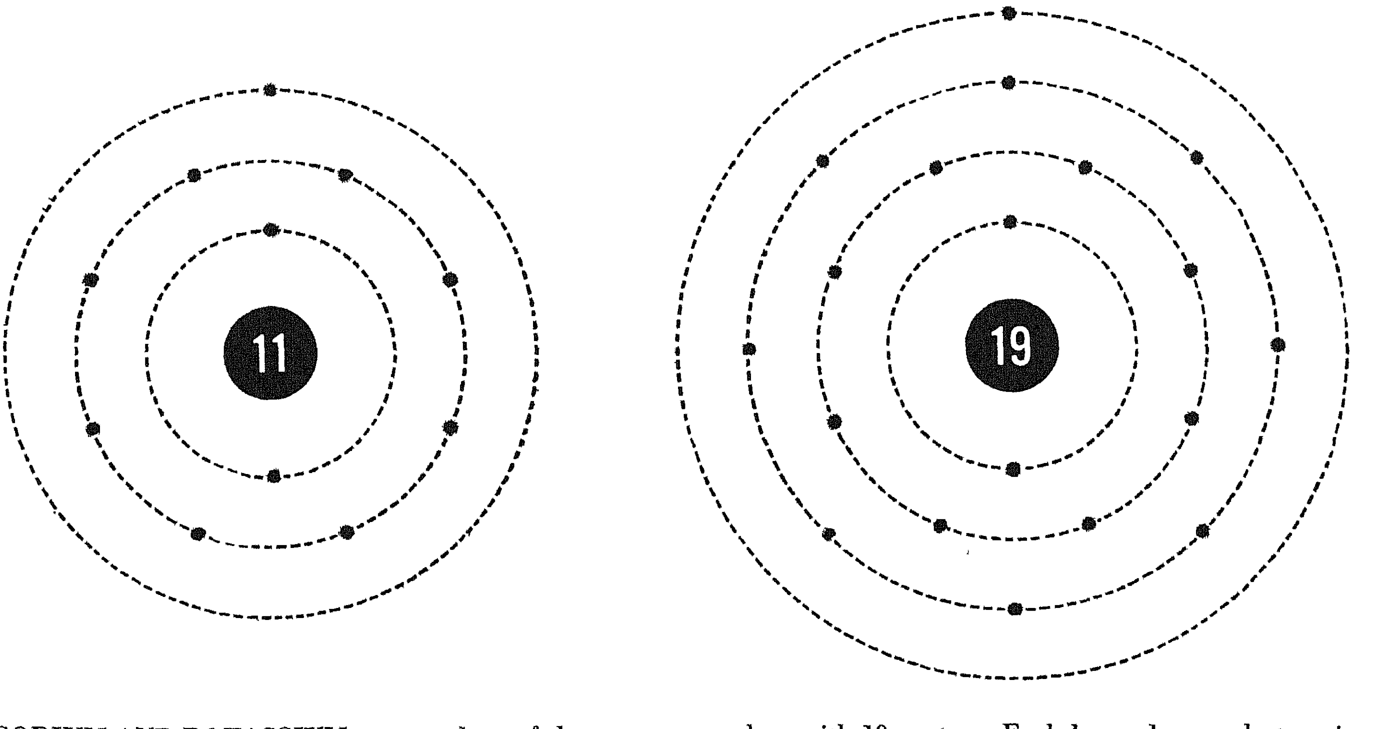
My colleague, Frederick C. Steward, has made a special study of the processes by which a plant is able to absorb potassium, and he has shown clearly that absorption always involves an increase in the rate of respiration. Furthermore, the respiration apparently supplies energy for protein metabolism. Potassium moves into such cells when protein metabolism is high. In the case of yeast, however, potassium moves into the cells when they are given glucose, *i.e.*, when their carbohydrate metabolism is high. When the yeast has consumed the sugar, the potassium returns to the solution outside the cells. There is some evidence that potassium is required for certain specific reactions within the cell in which phosphate is transferred from one compound to another. Presumably some such reaction is the basis for the important role played by potassium in so many physiological processes in both animals and plants.

In plants, as in animals, nearly all of the potassium is inside the cells. There is little or no sodium in plants, although some can be taken up if the concentration of sodium is very high in the soil or if there is a deficiency of other positively-charged ions which the plant would "prefer" to have. It is this relative absence of sodium from plant cells which gives to plant-eating animals their craving for sodium salt, a symptom which is very familiar to cattle farmers. Since plants can take up sodium if there is plenty available, it is not surprising to find this element in marine plants. This distinction between sea plants and land plants is a very old one; it was known at the time of Pliny the Elder that the ashes of the former made a hard soap and the ashes of the latter a soft soap. Eventually the former came to be designated as mineral alkali or sodium and the latter as vegetable alkali or potassium.

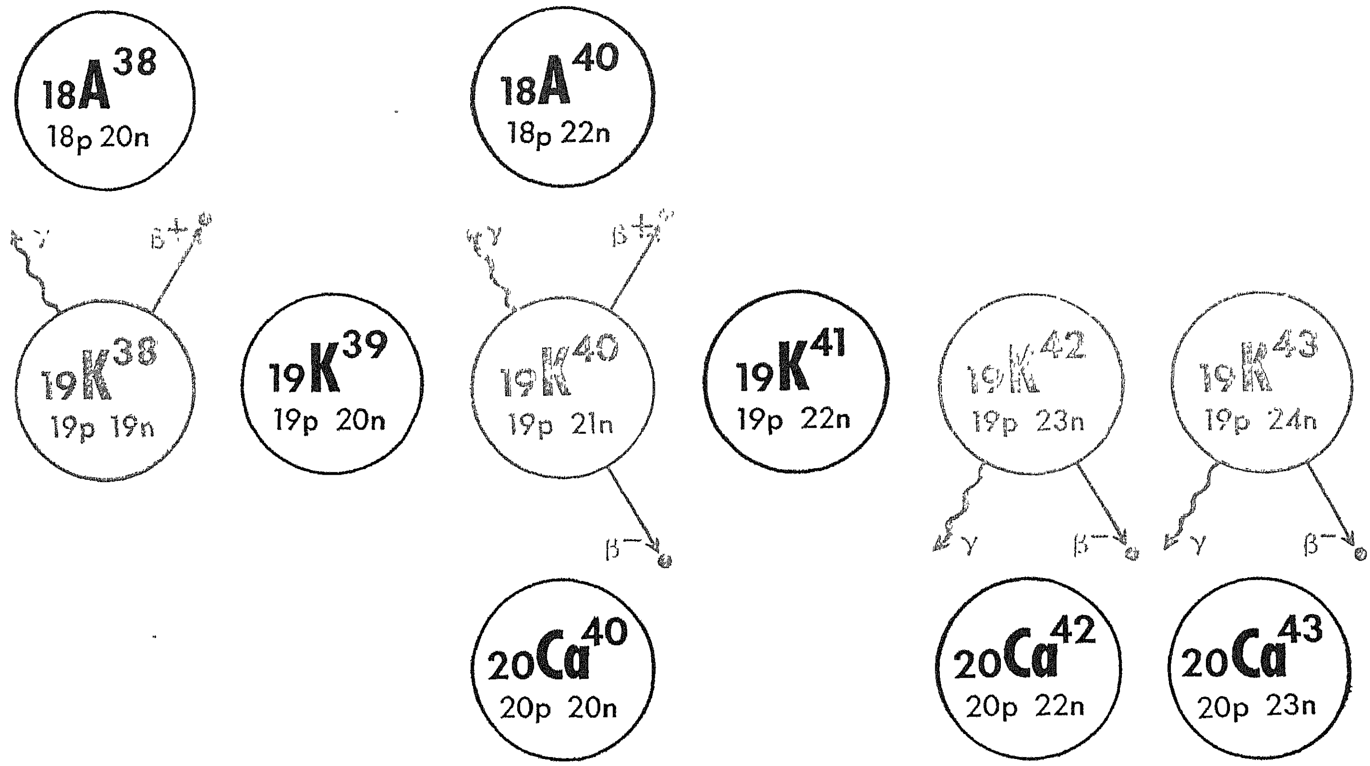
The most difficult and most fascinating of all the potassium problems is the mechanism whereby it becomes concentrated in the interior of living cells. The human body has approximately 175 grams of potassium. Of this only three grams is found outside the cells. The cells hold two thirds of the body water and 97 per cent of the total potassium of the body. On the other hand, the sodium of the body is located almost entirely outside the cells in the extracellular spaces—in the blood plasma, the connecting tissue and the fluid in the interstices between the cells.

The storage of potassium in cells may be regarded as a protective device to avoid the toxic effects that occur when the potassium concentration in the bloodstream increases unduly. If this concentration in the blood increases to more than three or four times normal, the beating of the heart will stop. With a little further increase, nerves cease to conduct their impulses and muscles fail to contract. If as little as six per cent of the cell potassium were allowed to escape quickly into the extracellular space, the organism would promptly die. Fortunately the cells of our bodies never release their potassium so long as they are alive, except slowly and in very small amounts.

The normal human intake of potassium is about three grams per day. It would not be difficult at a big banquet



SODIUM AND POTASSIUM are members of the same chemical family. Sodium has 11 electrons circling in three orbits around a nucleus with 11 protons. Potassium has 19 electrons circling in four orbits around a nucleus with 19 protons. Each has only one electron in its outermost orbit, which gives them similar chemical characteristics. Yet in animal systems potassium is normally concentrated inside the cells and sodium outside.



SIX NUCLEAR SPECIES of potassium are known, of which three are made artificially. The three natural isotopes are K-39, K-40 and K-41. K-39 accounts for 93.38 per cent of the potassium in nature. K-41 accounts for 6.61 per cent and K-40 for .01 per cent. Radioisotopes are shown in red. Protons are denoted by p, neutrons by n.

to eat enough potassium to put oneself "under the table" permanently, if the cells of the body did not watch over the rising level of potassium in the blood as the food is absorbed from the intestines. The cells can store 30 grams of extra potassium. The kidneys also help. They eventually excrete in the urine nearly all the potassium in food except small amounts needed for the growth of new cells, a little is also lost in perspiration and in the feces.

THE toxicity of potassium, curiously enough, was first discovered in a meat extract prepared by the German chemist von Liebig and put on the market as a food for infants about 1840. When this extract was fed to animals in sufficient quantity, the animals died, with symptoms later recognized as those of potassium poisoning. Fortunately human beings, and perhaps other animals, have a protective mechanism against concentrated potassium; they vomit if the stomach is offered too much of it. This has often been observed among physiology students when they drink rather concentrated solutions of potassium chloride, in accordance with laboratory direction sheets, to illustrate the excretory powers of the kidneys. When such experiments are not nauseously and abruptly terminated at the sink, it is found that half the potassium appears in the urine in about four hours.

Extraordinary records in kidney excretion have been observed in laboratory animals. In the writer's laboratory some mice were kept on a very high potassium diet and potassium was even added in their drinking water in amounts that they could barely tolerate. Every day for nine days they ingested an amount of potassium equal to the total contained in their bodies, but when they were killed and analyzed for potassium at the end of the experiment, they were found to contain no more potassium than normal mice of the same size. The kidneys, in other words, had been able to keep up with the excessive intake. More recently, Jonathan S. Thatcher and Arthur W. Radike at Ohio State University have given potassium to rats by stomach tube in increasing amounts. Thus conditioned, the rats were finally able to tolerate doses containing half the total potassium of the body, given four times at four-hour intervals. The rats could also be conditioned to tolerate this tremendous influx of potassium by preliminary treatment with extracts of the adrenal cortex. When the secretions of this gland are absent, the excretion of potassium by the kidneys is impaired and it accumulates in the blood. It would be expected, therefore, that injections of extracts of this gland would facilitate the excretion of potassium by the kidneys.

These experiments show how difficult it is to poison the body with potassium when it enters the bloodstream slowly, as it must from the intestines. If, however, potassium is injected quickly into the bloodstream, it is extremely toxic. It is much more toxic when injected into a vein than into an artery: from the vein it goes directly to the heart and may stop the beat, whereas from the artery it goes to some less sensitive capillary bed in the skin or muscles, where it diffuses through the porous capillary walls and is taken up by the tissue cells. Even in the heart potassium would not be fatal if it could get through the organ before it stopped beating. When the heart stops, however, the potassium is left in its chambers and coronary vessels, where it is most harmful. If the hand of a surgeon could reach in at this juncture and massage the heart before it dies of lack of oxygen, the heart would probably recover and resume its beat.

This suggests a practical method of resuscitation from electrocution. A strong electric current through the heart stimulates different parts of the heart at different stages in its recovery from the previous beat. Thus the coordination of the beat is destroyed and the effectiveness of the heart as a pump is nil. The heart muscle no longer beats rhythmically, but instead it seems to "squirm" in a haphazard manner. The individual fibers are still beating but they are out of phase with one another. The cardiologist calls this fibrillation. If potassium were injected at this stage in a suitable concentration, it would stop the heart. If the potassium were then displaced by a second injection of sodium chloride or eliminated by manually squeezing the heart, the normal coordinated beat could

be restored without any residual damage. Such treatment requires great skill with the hypodermic needle, however, and to be useful must obviously be prompt.

When the heart dies, its cells give up some of their large potassium stores and the element diffuses into the blood. Thus lethal concentrations of potassium are always found in the heart after death. (Writers of detective stories might well take note of this fact. Potassium would be an undetectable poison, for chemical analysis of the blood of a victim killed by it would not show any foreign substance.)

It is a striking and puzzling fact that this substance, which is so toxic in the blood, is stored safely in large amounts inside the cells, where it is not only harmless but is probably required for the proper metabolism of the cells. And the statement that potassium is toxic in the bloodstream also requires some qualification. If the blood had no potassium at all, the heart would be just as much incapacitated as with too much potassium. For its normal beat the heart requires in the blood plasma about 100 parts of sodium to four parts of potassium and two parts of calcium. These are approximately the relative concentrations of the three substances in the ocean. In spite of the great changes in living forms wrought by evolution, the basic living cells apparently still feel the need of a salty environment like that in which life presumably began.

PHYSICIANS now realize the dangers of too low a level of potassium in the blood. There is a hereditary syndrome called familial periodic paralysis in which the muscles become paralyzed, although fortunately it does not affect the muscle of the heart, at least for a time. The disorder can be treated by giving potassium by mouth. A potassium deficiency also sometimes occurs in patients who are given fluids intravenously in large amounts. If these contain no potassium and if the patient is not able to take a regular diet containing a supply of potassium, there may be so large a loss of potassium through the kidneys that the deficiency is felt: muscles become weak and death may result Persistent diarrhea in infants likewise may deplete the body potassium, for all the intestinal secretions contain considerable amounts of potassium—three or more times as much as the blood plasma. Ordinarily this potassium is reabsorbed into the body, but when the intestines are not functioning properly it is lost. A dose of potassium at a critical time may often relieve a paralysis and save a life.

A method for quickly analyzing the potassium in body fluids has recently been developed and is rapidly making its appearance in hospitals. The instrument, called the flame photometer, makes it possible to find out quickly whether a potassium deficiency is threatening. It is essentially a gas burner into the base of which the solution to be investigated is introduced in the form of a fine mist from an atomizer. Each solution gives the flame a characteristic color. Light from the flame is then passed through a filter which isolates wavelengths characteristic of potassium or whatever other substance is to be identified. The intensity of this light is measured by a photoelectric cell. By the use of such an instrument, John S. Lockwood and his staff in the general surgical service at the Columbia University Medical Center believe that they have been able in the last 18 months to save the lives of 10 patients who would otherwise have died

The flame photometer is certain to show other applications of potassium treatment in disease in the next few years. At least two other applications have already been worked out by the traditional laborious chemical methods In cases of surgical shock the blood gains potassium not only from tissues actually injured by the operation or accident but also from the liver and other tissues where it is stored This potassium poisoning, while not apparently the primary cause of death, may sometimes be a contributing factor. Potassium may also be important in Addison's disease, in which the secretions of the adrenal cortex are deficient. Among their other functions, the hormones of this gland serve to retain sodium in the body and to excrete potassium. In their absence excessive amounts of sodium are lost, and potassium is not properly excreted by the kidneys. Thus the symptoms of potassium poisoning may appear. Low-potassium foods or the administration of sodium chloride will prolong life in this condition.

Although potassium belongs mostly inside the cells, it must not be supposed that it is sealed up in them by an impermeable membrane. If a little radioactive potassium (the isotope K-42) is injected into the blood, it rapidly exchanges with the common isotope K-39 in the cells, showing that the membranes are permeable to potassium. This exchange is particularly rapid in the liver, which seems to be a sort of first line of defense against injected potassium; it is particularly slow in the brain and in the red blood corpuscles, which seem to maintain their normal volume by a relative impermeability to potassium. If potassium went into the red cells freely it would take water and chloride with it and swell the cells until they burst.

The fact that potassium does enter the red cells slowly shows that there are some active metabolic processes in cells which can take potassium in or let it out as needed. When the cells have plenty of sugar to burn they may take in potassium, but when the sugar is used up the

	Na	K
Sun	10.0	14.5
Stony meteorites	.69	.18
Igneous rock	2.85	2.60
Sedimentary rock	.82	2.32
Ocean	1.07	.039
Human body	.262	.238
Plants	0	1-7

PERCENTAGES of sodium and potassium in natural systems are given. Values for sun are in arbitrary units.

	K
Total	175
Total extracellular	3
Whole blood	8
Blood plasma	.3
Daily intake	3
Daily starvation loss	.6
Intestinal secretion per day	1.25
Harmless daily intake	20

GRAMS of potassium associated with the human system are given. Most of 175-gram total is within the cells.

potassium comes back into the plasma. In this respect they resemble yeast cells. When red cells are stored at low temperatures (as in the Red Cross blood banks), potassium slowly leaks out into the plasma. If the cells are warmed up again, the metabolism is increased and potassium returns to the cells from the plasma. It is remarkable indeed that potassium very frequently seems to follow the sugar into or out of the cells. Thus if an animal is startled or subjected to a situation, such as acute lack of oxygen, sufficiently critical to cause it to secrete adrenalin, some of the sugar comes out of its liver into the blood and the potassium concentration of the blood simultaneously goes up. Likewise if much sugar is put into the blood, it moves into the tissues and takes some potassium with it. In this way sugar may bring on an attack of familial periodic paralysis in the victims of this disease.

POTASSIUM also moves about in the body during exercise. When muscles contract, they lose some of their potassium and absorb a nearly equivalent amount of sodium from the bloodstream in its place After exercise, when the muscles are recovering, the reverse process takes place. There must of course be some limit to this process, else one might run oneself to death by building up the potassium in the blood to dangerous levels. Such potassium as is lost from the active muscles is normally taken up by inactive parts of the body. Possibly also a high level of potassium in the blood may make the muscles feel tired or make them less able to contract, so that the leakage from the muscles would be self-limiting.

There are few bodily processes that are not influenced in some way by changes in the concentration of potassium in the blood plasma, which is the effective environment of all the cells of the body. Yet potassium is only one of the factors in this environment. When one of these factors changes, others usually change also. Among these other factors are sodium, chloride, calcium, magnesium and the degree of acidity or alkalinity. On account of this interdependence of many factors it is impossible to say that potassium is the most important factor; it is sufficient to designate it merely as one of the factors about which a great deal has been learned in recent years.

One of the chief characteristics of a living cell is the high potassium content of its interior. If we knew just how the cell manages to maintain this content, so different from that of its environment, we should know a lot about what a living cell really is. There are two theories in circulation today. According to the Conway-Boyle theory, potassium enters the cell to combine with or to neutralize organic acids that are formed inside the cell and have molecules too large to come out through the cell membrane, they can be reached only inside the cell Sodium, on the other hand, cannot penetrate the membrane to serve this purpose, or to exchange with potassium. Its ion, which is characteristically surrounded by a shell of water molecules, is too large This theory has been stated in exact mathematical terms by E. J. Conway of Dublin and has been supported by some very good experimental data. Conway has succeeded pretty well in answering most of the objections to his theory, but he has not satisfactorily explained the fact that muscles do seem to be permeable to sodium, as shown by experiments with a radioactive isotope of sodium, Na-24.

The second theory to explain why potassium rather than sodium is accumulated in cells is that sodium does enter the cells but is pumped out again by some unknown mechanism. This theory was first proposed by Robert B. Dean at our laboratory. A pump which consistently cleared the cells of sodium would explain all the observations, but the nature of such a pump is entirely unknown and except in a mathematical sense the suggestion contributes little to an understanding of the real mechanism. To the specialist these theories are of absorbing interest, however, for they stand at the very center of the organizational problem of living material.

The high concentration of potassium inside cells is believed to have an important effect on the electrical currents of the body. The membranes of cells appear to be permeable to potassium, yet there is a marked difference in the concentration of potassium on the inside and the outside of a membrane. It is as if the small, positively-charged potassium ion found itself able to penetrate the membrane but was held back by the large organic phosphate or protein molecule with which it was combined. This results in an orientation of molecules near the surface of the cell, with the positively-charged potassium pointing outward and the negatively-charged phosphate pointing inward. The result is a polarization of the membrane, and a difference in electrical potential of about seven hundredths of a volt between the inside and outside of the cell.

If this is a muscle or a nerve cell, which can be stimulated to contract or conduct a nerve impulse, it is believed that the membrane suddenly becomes more permeable, thus temporarily diminishing the potassium polarization and causing a brief pulse of current. Potassium therefore appears to be responsible for the electric currents familiar as electrocardiograms and brain waves. There are also many other electrical pulses known to physiologists originating in all the nerves and muscles of the body. Thus the energy of stored potassium can be transformed by the body into electrical energy.

The skin of animals, including man, is polarized in a similar way, except that the inside is positive and the outside is negative The cause of this difference in potential is not precisely known, but it may be fundamentally related to differences in the distribution of potassium in the various layers of the skin. Whatever the explanation, it is well known that when the skin is even slightly injured, the injured area has a negative charge. The process of healing can be followed by measuring the potential of the injured area from time to time.

From the foregoing discussion it is evident that potassium moves about in the body by diffusion, absorption or secretion. Diffusion from a high concentration to a lower one we can understand, but absorption and secretion are words to conceal our ignorance. Potassium probably enters the blood from the intestine largely by diffusion, but some absorption process may be involved. Potassium must enter cells against the concentration gradient, and here also there is evidence that some active metabolic process participates. From the bloodstream, potassium reaches cells by diffusion through the walls of the capillaries. From the kidneys, potassium leaves the body by filtration of fluid and salts and by active "secretion."

ALL of these processes would seem to offer some opportunity for a separation of the different isotopes of potassium. Rates of diffusion are inversely proportional to the square roots of the atomic weights, so the rates of diffusion of K-39 and K-41 might differ by 2.4 per cent. For this reason it is conceivable that during a lifetime there might develop in the body an excess of either the lighter or the heavier isotope, depending upon which one of the various diffusion processes mentioned might be the more important. Many efforts to discover some isotopic separations of this sort have been made. A. Keith Brewer of the Department of Agriculture has studied the relative abundance of K-39 and K-41 by the use of the mass spectrometer. He has reported a relative deficiency of the heavier isotope in bone marrow and a relative excess in the auricles of the heart. He has also found some excesses of K-41 in kelp and other plants. But these interesting findings require further confirmation.

In the writer's laboratory an effort was made to determine the relative abundance of the radioactive isotope K-40 in potassium isolated from human ashes obtained from the crematorium of the medical school. Counts were then made with a Geiger counter of the number of disintegrations obtained per second from this human potassium, as compared with another sample of laboratory potas-

sium treated in exactly the same manner. Averaging many experiments together, we seemed to find a relative deficiency of K-40 of about 2.3 per cent in human potassium, but the difference was so small as to be of somewhat doubtful significance. More recently Loren Mullins, who made the original experiment, has repeated it with better apparatus and has found no differences in the relative abundance of K-40 in samples derived from lava rock, beach wood, horse bones, cow bones and ordinary commercial sources What systematic error may have entered into the experiments we performed we cannot say, but it now seems very doubtful that there is any natural separation of potassium isotopes by living cells.

The importance of the natural radioactivity of potassium in geological processes has already been mentioned. It remains to discuss the possible biological role of these ionizing disintegrations, which are occurring in our bodies continuously at the rate of about 3,500 per second, or about three disintegrations per gram of tissue every minute. That these discharges of electrons from K-40 have important effects on the heart beat, on nervous activity and on photosynthesis in plants has often been suggested, but no proof has been forthcoming. Certainly the paralyzing effects on the heart and muscles of abnormally low potassium in the blood plasma are not due to lack of this radioactivity, because plenty of radioactivity reaches the cells from the potassium within them.

It is of course possible that ionizing radiations may have some obscure effect on long-term processes such as aging. It would indeed be interesting to study the aging of animals that were protected from exposure to cosmic rays and were raised on potassium free of the radioactive isotope. The experiment is impossible to carry out at present. In any case there is no reason to expect that it would provide the key to immortality.

The possibility that K-40 or cosmic rays may cause mutations in plants and animals seems more plausible, but a calculation of the intensity of such radiation to which their germ cells are exposed indicates that the chances of this are very remote. K-40 produces an intensity of radiation in the body which is of the same order of magnitude as that caused by cosmic rays. But it is a much less potent source of chronic radiation than radium, which tends to accumulate to a small extent in the bones. Not even radium, however, appears to reach dangerous levels under the normal conditions of life.

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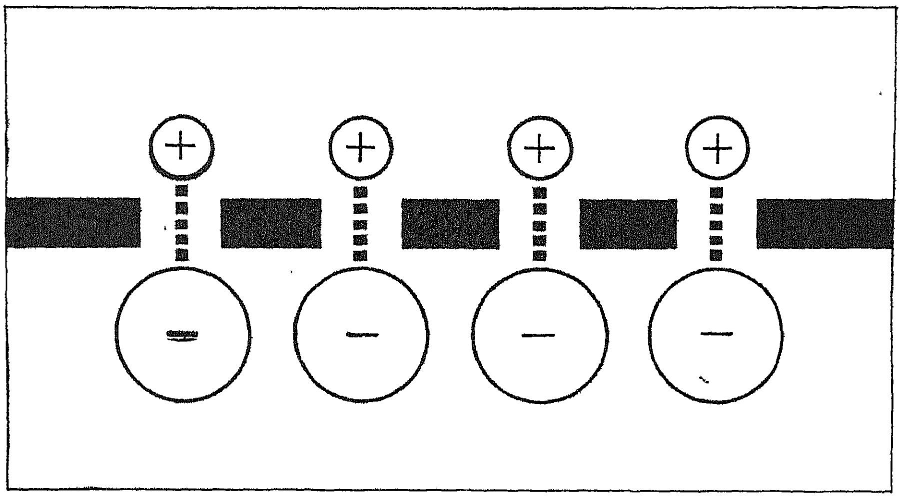
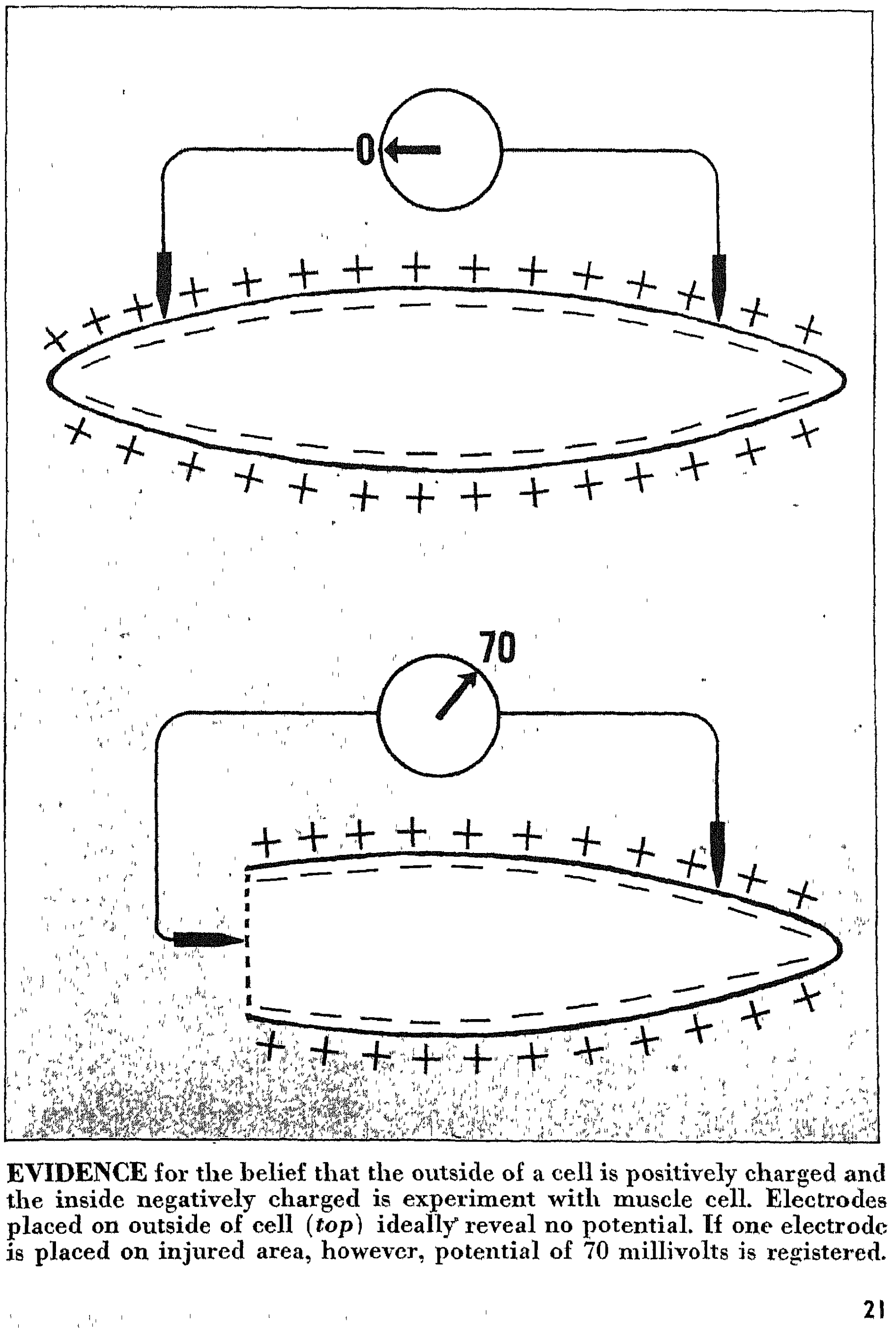
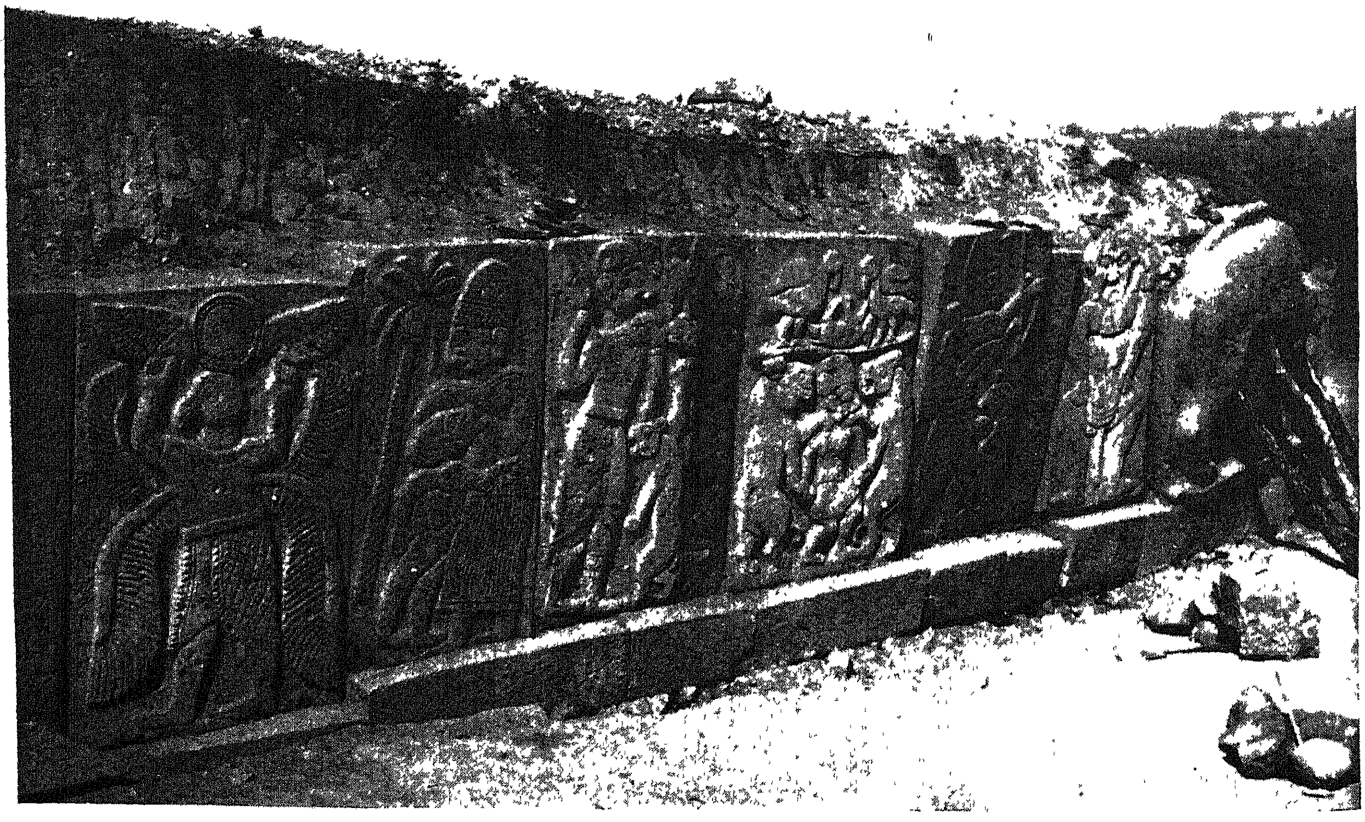


CELL may derive its electrical charge from the association of potassium with a large molecule. Positively-charged potassium atom can pass through permeable cell membrane (*black*), while negatively-charged large molecule cannot. Outside of membrane is thus positively charged and inside negatively.



EVIDENCE for the belief that the outside of a cell is positively charged and the inside negatively charged is experiment with muscle cell. Electrodes placed on outside of cell (*top*) ideally reveal no potential. If one electrode is placed on injured area, however, potential of 70 millivolts is registered.

ONE SIDE of the corridor at the northern entrance to the Karatepe citadel is lined by stone slabs carved with bas-reliefs and old Phoenician inscriptions. When Dr. Bossert first came to the site, only the tops of these slabs were visible above the ground. The bas-reliefs and inscriptions were later laid bare by excavation.

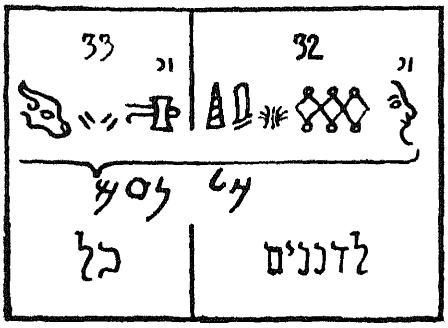


OTHER SIDE of same corridor is lined by slabs carved with bas-reliefs and Hittite hieroglyphs. The hieroglyphs appear most clearly at the far left. Text of both Hittite and Phoenician inscriptions says that citadel was built by Asitawandas, King of the Danuna and member of the dynasty of Mopsos. Citadel was called Asitawanda.

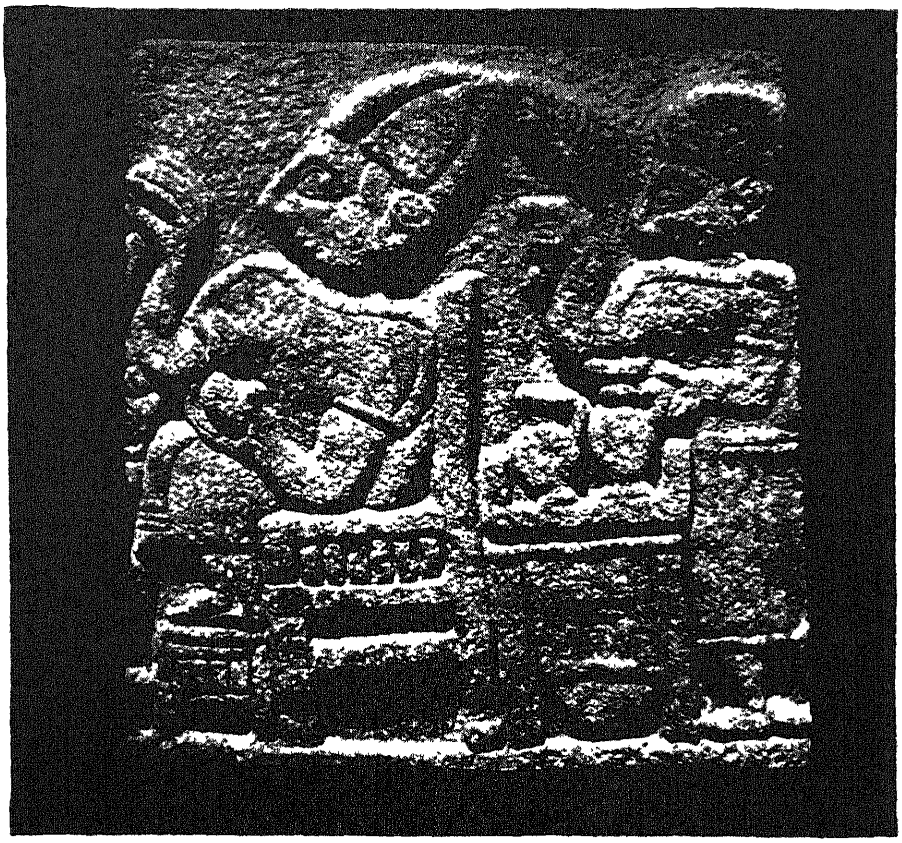
HITTITE CITADEL

Passageway on a hill in Turkey is the key to undeciphered script of a dead civilization

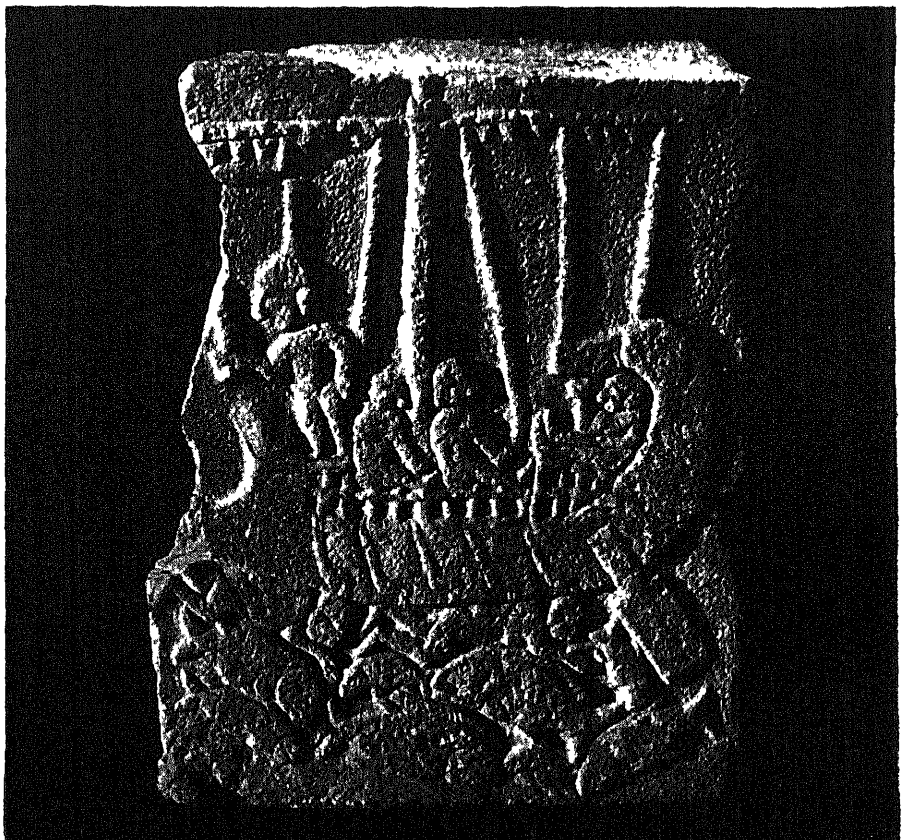
THE Hittites, the energetic and civilized people who ruled a great part of Asia Minor and Syria for most of the second millennium B.C., wrote both a cuneiform and a hieroglyphic script. Since their discovery in 1812 the hieroglyphs have resisted all attempts to translate them. Recently, however, H. T. Bossert of the University of Istanbul and his co-workers found the key to the undeciphered script. Sometime before 730 B.C. a late Hittite king named Asitawandas had built a citadel on a hill called Karatepe in what is now southeastern Turkey. The citadel could be entered through two corridors decorated on both sides with inscribed and sculptured stone panels. One side of each corridor, Dr. Bossert discovered, is inscribed with hieroglyphs. The other is inscribed with the translatable old Phoenician script. Like the Greek inscription on the Rosetta Stone, which runs parallel to two Egyptian inscriptions, the Phoenician script of Karatepe tells the same story as the hieroglyphs Dr. Bossert's discovery also provides the key to other Hittite hieroglyphic inscriptions, many of which have been found in Asia Minor. When enough of these inscriptions have been translated, they are expected to fill a gap of some six centuries in the history of a relatively little-known region and people.



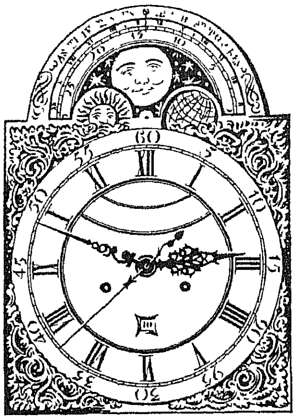
THREE SCRIPTS are compared. At top is hieroglyphic. In center is old Phoenician. Below: modern Hebrew.



BAS-RELIEF shows Asitawandas (*left*) at a banquet. Great curved nose and sloping forehead were characteristic of the Hittites. Asitawandas was probably the last Hittite king before his country became an Assyrian province.



BAS-RELIEF of a galley built by the Danuna is one of earliest representations of a seagoing vessel. Asitawandas' Mopsos dynasty is famous in Greek legends. Karatepe inscriptions are first evidence that it was not Greek.



SCIENCE AND

Mutation by Streptomycin

A TOTALLY unexpected property of streptomycin, the antibiotic derived from a soil mold (*see page 26*), has opened up an exciting new branch of research. It has been found that streptomycin can cause a mutation in plants which makes them incapable of manufacturing chlorophyll, the green coloring matter of plants.

The discovery was made by Albert Schatz of the Sloan-Kettering Institute and Luigi Provasoli and S. H. Hutner of the Haskins Laboratories. They were using streptomycin to prepare bacteria-free cultures of euglena, a microscopic flagellated alga that occupies a twilight zone between the plant and animal worlds. After a few days' incubation with streptomycin the alga surprisingly lost its green color and its ability to carry on photosynthesis. Even when the alga was transferred to a medium that contained no streptomycin, it failed to regain its color, showing that the organism had undergone a hereditary change. The modified euglena was kept alive only by feeding it organic material that it had formerly manufactured for itself.

Microscopic examination showed that streptomycin destroyed the chloroplasts, the tiny chlorophyll-bearing bodies of the green plant cell. It had no other discernible effects. Other investigators obtained similar results in higher plants by treating seedlings with streptomycin.

The phenomenon has several interesting consequences. It provides a simple test for the presence of streptomycin. It affords a method for creating parallel strains of green and colorless plants for studies of photosynthesis. And it provides a rare opportunity to direct the mutation of a living organism in a predictable way. Most other mutagenic agents such as X-rays merely increase the frequency of mutations; so far as is known they do not control the specific kind of mutation that may result. The only other agent that is known to produce "directed" mutations is desoxyribonucleic acid, a constituent of genes. It alters three varieties of bacteria in a specific way—the pneumococcus, E. coli and Shigella. Its action converts one strain into another, and the conversion is reversible. Streptomycin produces quite another type of change—a "loss" mutation rather than a conversion.

Cytochrome C for Senility?

CYTOCHROME C is an enzyme that plays a central role in the utilization of oxygen by the body cells. It has been studied as a possible factor in cardiovascular disease. Now two Virginia physicians find that it may be important in maintaining the functioning of the brain in aging people. W. O. Klingman and R. W. Garnett, Jr., of the University of Virginia Hospital, report that treatment with the enzyme reduced the irritability and vagueness of 11 of 17 elderly patients who had cerebral arteriosclerosis and similar mental disorders of senility.

The mechanism by which cytochrome C produces this effect is unclear. It is known that the tissue of the central-nervous system is particularly sensitive to oxygen deprivation. Perhaps one factor in mental senility is an inadequate supply of oxygen to the brain, as a result of degenerative changes in the cerebral blood vessels during the aging process.

The Virginia test followed the discovery by Samuel Proger and D. Dekaneas, of the New England Medical Center, that cytochrome C overcomes the effect of oxygen deprivation upon mental functioning in simulated high-altitude flights. The enzyme has no effect on emotional difficulties. Only people with previously normal personalities have been helped, and the improvement lasts only as long as the treatments are continued.

Cosmic Rays

COSMIC rays have usually been assumed to come from interstellar space. R. D. Richtmyer of the Institute for Advanced Study and Edward Teller of the University of Chicago now suggest that they may originate within the solar system. The two physicists have advanced the hypothesis that cosmic rays are born near the sun and are distributed throughout the solar system by an electromagnetic field that extends from the sun out past the outermost planet.

Enrico Fermi of the University of Chicago had suggested that cosmic rays might stem from fields wandering in intergalactic space; but his proposal did not account for the fact that nuclei of heavy elements, as well as protons, are found in cosmic radiation. Richtmyer and Teller find that both protons and heavy nuclei could be accelerated to the enormous velocity of cosmic-ray particles by an extended magnetic field of solar origin. Only a negligibly small fraction of the sun's energy would be needed to generate a field of the necessary intensity.

Such a magnetic field has not yet been actually observed; the intensity would be too low for it to be easily detected. The field would not only accelerate protons and heavy nuclei to cosmic-ray energies, but would distribute them throughout the solar system with the high degree of uniformity which is an outstanding characteristic of cosmic radiation. The field would also keep them circulating until they struck a body like the earth. They might circulate for periods of 1,000 years to 50 million. The British-born physicist W. F. G. Swann was the first to suggest, in 1933, that the sun might be the source of cosmic rays, but he had in mind a quite different mechanism.

Wind Power

IT HAS been quite a while since the wind was last considered seriously as a major source of power, but the United Nations now has before it a proposal that at least merits study. Its author is Percy H. Thomas, an engineer of the U.S. Federal Power Commission. He offers the ingenious suggestion that wind-driven generators be combined with water-power and steam units in an integrated system, in much the same way as water power and steam are coupled now.

Wind and water power would work together, the one ironing out the irregularities of the other, with steam "firming up" the power delivered by the two. An experimental generator built in Vermont before the war indicates that wind generators, cheap to build and operate, would deliver electricity at lower cost than either steam or water power. Thomas presented his proposal to the UN Scientific Conference on the Conservation and Utilization of Resources.

Sky Survey

ALTHOUGH the sky has been photographed extensively for half a century, it is so vast that only a comparatively small portion of it is yet explored. The Palomar Mountain observatory, home of the 200-inch Hale telescope, has now undertaken the task of providing astronomers with a systematic atlas of the heavens. The project, sponsored jointly by the California Institute of

THE CITIZEN

Technology and the National Geographic Society, and directed by Edwin P. Hubble, will take four years to complete.

For this job the observatory will use its big Schmidt photographic telescope, it would take 50 centuries to cover the same area with the tiny field of the 200-inch. The Schmidt, specially adapted to photographing wide areas, is the largest of its kind in the world. It probes the skies to a depth of 300 million light-years—only a third as far as the 200-inch, but 10 times as far as any previous wide-angle photographic telescope.

The survey will record some 500 million stars and perhaps 10 million extragalactic nebulae on 2,000 plates. Photographs will be made through both red and blue filters to assist astronomers in determining the stars' colors. From the eminence of Palomar, the Schmidt can cover about three quarters of the heavens with high accuracy. An additional 10 per cent can be covered to some degree. The atlas, comprising 20 volumes, will be sold to other observatories at cost, approximately $2,000 per set.

Britain's Royal Observatory, now being moved from its historic site at Greenwich to Hurstmonceux, will have in its new site a new 98-inch telescope, the third largest in the world and the largest outside the U.S. The mirror for it is a gift of the University of Michigan's McGregor Fund. The mirror was poured and ground during the 1930s for a new observatory which was never completed for lack of funds. The McGregor Fund trustees donated the mirror, which has been in storage, to the Royal Observatory during the recent American visit of Sir Herbert Spencer Jones, the British Astronomer Royal.

Science Foundation

THE proposed National Science Foundation, lost in the hurly-burly of more controversial legislation during the past year, appears to be approaching a decision. A bipartisan bill designed to meet the objections to the measure vetoed two years ago by President Truman has passed the Senate. A generally similar bill, sponsored by Representative J. Percy Priest, Tennessee Democrat, has been reported favorably by the House Interstate and Foreign Commerce Committee It is possible that the final measure may clear both houses before Congress adjourns for the summer. If not, Congress can continue work on the same bills in the fall, for unfinished bills need be reintroduced only when a new Congress is elected. Thus in all likelihood the Foundation will come into existence by the end of 1949.

Atomic Energy

THE Congressional investigation of the Atomic Energy Commission, which began with a display of angry headlines in May, droned on through the heat wave of June and July. It appeared that the tangible results would be two. 1) the requirement of a loyalty oath from recipients of AEC fellowships, already ordered; 2) sharper scrutiny of atomic energy contracts by Congress. Senator Brien McMahon, chairman of the Joint Committee on Atomic Energy, introduced a bill that would require the AEC to obtain from Congress advance approval of all its projects and programs, at the time when it presents its budget each year

In the hearings on Senator Bourke B Hickenlooper's charges of "incredible mismanagement" against the Commission, Hickenlooper offered in evidence: 1) that a school at Hanford originally expected to cost $1,786,000 had finally cost $3,966,000; 2) that the town of Richland, where workers in the Hanford plutonium works live, was run on "fascistic" lines without "room for free enterprise"; 3) that the AEC was going ahead with a $10 million natural gas pipeline to Oak Ridge despite the objections of a House committee headed by Representative Carl Durham of North Carolina. The AEC replied: 1) the school had to be built on a poor site, and construction had to be rushed to avoid losing employees with families; 2) Richland had been even more restricted during the Manhattan District regime, and restrictions were gradually being reduced; 3) the gas pipeline would not only safeguard Oak Ridge against an interruption in its coal supply, but, because of the low cost of natural gas, would pay for itself in eight years.

The hearings finally laid to rest the alarming case of the missing U-235. The Joint Committee's own technical consultant, Ernest W. Thiele of the Standard Oil Company of Indiana, joined the Federal Bureau of Investigation and the AEC in dismissing the possibility of espionage in the incident

Cleared Scientists

APPARENTLY there are comparatively few scientists in the U.S. who have not been investigated at one time or other by the Federal Bureau of Investigation A recent report by the Scientists' Committee on Loyalty Problems, an affiliate of the Federation of American Scientists, shows that security clearance is now a requirement for a very large proportion of Government-subsidized scientific work. Many, perhaps most, of the scientists who work on projects supported by the Atomic Energy Commission, the Army, the Navy and the Air Force, or their contractors, must obtain such clearance. Some university and industrial laboratories with military or AEC contracts require clearance for all employees, whether or not they are engaged in secret work, as a matter of "administrative convenience."

The Scientists' Committee, headed by the Princeton astronomer Lyman Spitzer, Jr., observed that the AEC is the only agency that has published its criteria for clearance. All of the agencies except the Navy allow hearings to employees accused of political unreliability, but the hearing procedures vary greatly. The armed forces have a joint Personnel Security Board and a joint Review Board to which employees of their contractors may appeal. The latter board is composed mainly of military men; its hearings are secret and no notes may be made by the defendant or his lawyer.

Prescription Refills

THE U.S. Food and Drug Administration has launched a campaign to end the widespread practice of refilling prescriptions without specific authorization from a physician. The campaign is directed particularly toward imposing tighter control over the sale of barbiturate sleeping tablets, which cause several thousand deaths a year The FDA also wants to bring under control the sale of benzedrine, sulfa drugs, antibiotics and other powerful new pharmaceuticals.

The Administration is proceeding under the Food, Drug and Cosmetics Act of 1938. A U.S. Supreme Court decision last year, holding that a drug manufactured in one state and sold in another was in interstate commerce, placed virtually all retail drug sales within the FDA's province.

Meetings in September

AMERICAN Psychological Association. Denver. September 6-10.

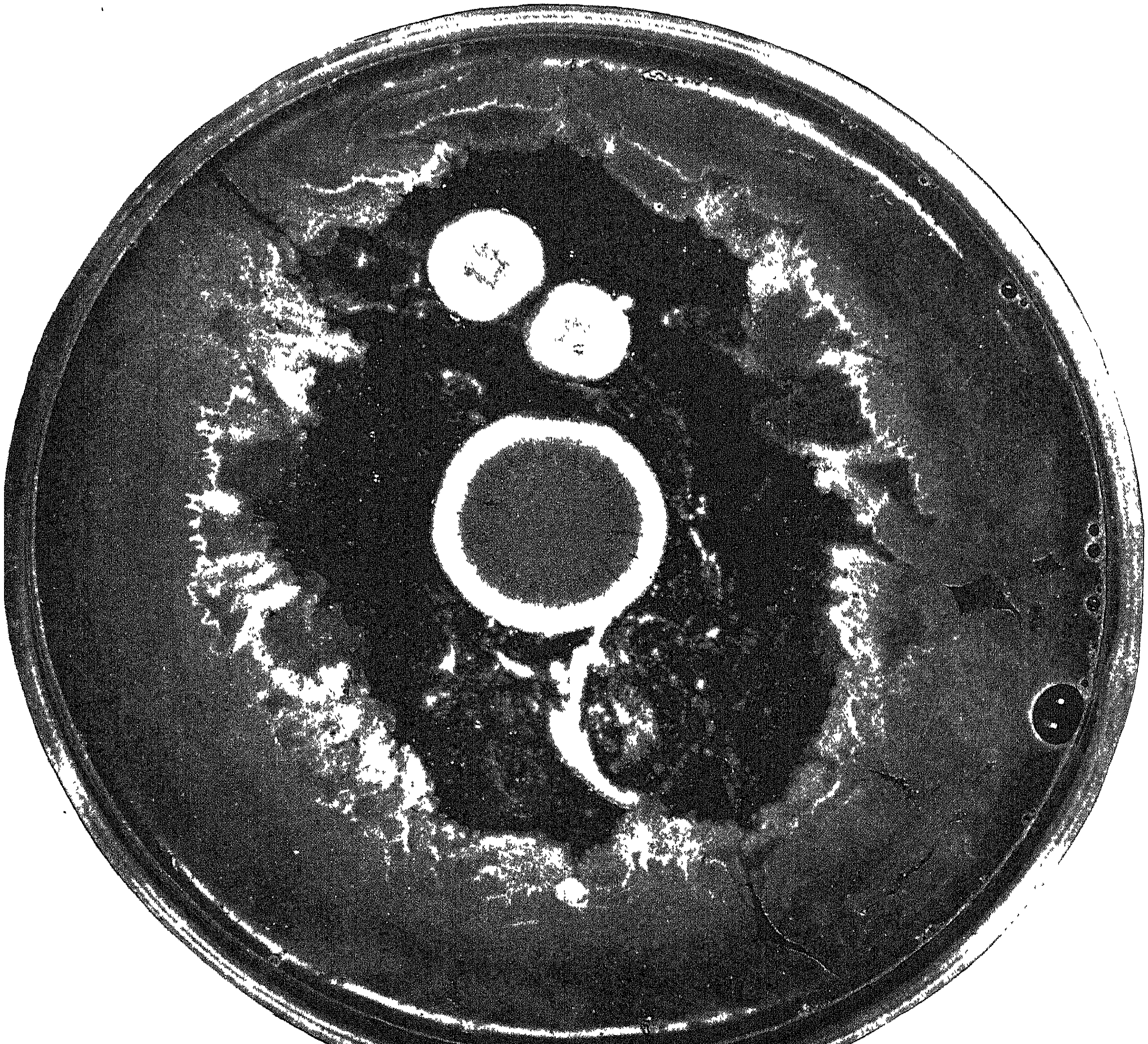
American Chemical Society. Semiannual meeting. Atlantic City. September 18-23.

American Society of Mechanical Engineers. Erie, Pa. September 28-30.

THE ANTIBIOTICS

The competition of microorganisms has provided man with powerful agents against infection. Presenting a review of their discovery and their development

by George W. Gray



PENICILLIUM NOTATUM grows in three white-bordered colonies on an agar-filled Petri dish. Also growing on the agar is a colony of microorganisms. Penicillin diffusing outward from the Penicillium has killed or inhibited the microorganisms. It was this effect that led Alexander Fleming to the discovery of penicillin in 1928.

THE quantity of garden soil one can easily pick up between the thumb and forefinger amounts to about one gram. Within that thirtieth of an ounce is a teeming world of living things—perhaps as many microbes as there are human beings on the earth. Estimates based on actual counts under the microscope indicate that a gram of rich humus contains thousands of millions of microorganisms, both plant and animal. Other tests reveal the presence of innumerable viruses too small to be seen beneath the optical microscope.

This crowded world of the soil is a highly competitive society in which one finds both cooperation and antagonism. Some of the microbes have a closely knit community of interests. One species will assist another in breaking down complex compounds of dead organic matter to simpler substances, which both then utilize as food. These natural scavengers, or saprophytes, constitute an organized microbial economy, with mutual dependence, division of labor and sharing of benefits. Some microbes live by attacking and destroying other living things. Not only may a parasite attack a saprophyte or another parasite, but the same saprophytes that work together in harmonious teamwork may, under changed conditions, fight one another in competition for food or other advantages. The soil is a battlefield of the universal struggle for existence.

Some microbes fight the battle with chemical compounds that destroy their competitors. Whether there is purpose in this chemical warfare we cannot say. It may be that the blue-green mold exudes penicillin as the human body exudes sweat, and that certain microbes of disease just happen to be sensitive to this substance. Whatever the reason and the process, numerous microbes produce and release into the soil chemical by-products that poison other microbes. It is these substances that are called antibiotics.

The discovery that some of the antibiotics also protect man and assist in fighting human infections has set bacteriologists, biochemists and other specialists on a grand quest. Soil organisms from many parts of the world have been sought out and tested for the protective chemicals they produce, and in this way several hundred antibiotics have been discovered. Most are too toxic for internal use, but four have proved strikingly effective against a wide range of human diseases. They are penicillin (first administered systemically to human cases in 1941), streptomycin (1944), Chloromycetin (1947), and aureomycin (1948). Penicillin and streptomycin are each being produced in the U.S. at the rate of about six and a half tons per month, while Chloromycetin and aureomycin are rapidly approaching large-scale industrial production. A still more recent find, neomycin, was announced a few weeks ago to give highly promising results in test tubes and animals, and physicians await the clinical tests which will determine whether or not it is medically useful.

Antibiosis

Our knowledge of antibiotics dates back to the time of Louis Pasteur. In 1877, during his pioneering studies of anthrax, Pasteur noticed that a colony of the bacteria suddenly stopped growing and presently died. He searched for the cause of this mysterious destruction and traced it to the presence of other bacteria drifting in the air which chanced to settle on the culture medium. These alien bacteria possessed the power to inhibit the life processes of the anthrax bacillus, and Pasteur prophesied that the antagonism of one species of microbe for another might prove to be of practical service to medical science. Other bacteriologists noticed the same effect with a variety of microorganisms, and in 1899 the English botanist H. M. Ward provided a name for this microbial antagonism. He called it antibiosis.

The first antibiotic to be used medicinally was pyocyanase, a substance produced by the blue-pus bacillus, which was found to inhibit the growth of the diphtheria organism. This discovery in 1899 was hailed as a step in the conquest of diphtheria; in practice the results were disappointing, and after a series of futile trials pyocyanase retired into the limbo of unsuccessful drugs. During the next four decades microbiologists again and again hit upon new antibiotics in the course of their researches, but few of them advanced far beyond the test-tube stage or became known outside the laboratories. In 1928 Alexander Fleming of London came upon the antibiotic which he named penicillin. He published a paper recording his experiments, but his discovery lay idle and unused for a decade.

In 1939 Rene J. Dubos of the Rockefeller Institute for Medical Research described a bacterial exudate that showed a powerful antagonistic effect against 13 strains of the blood-destroying streptococci, two strains of the golden staphylococci that cause boils and abscesses, and eight virulent varieties of the agent that causes pneumonia. These results attracted attention on both sides of the Atlantic. In many laboratories microbiologists began a reinvestigation of the known antibiotics to see if among them any other possibly useful drug could be found.

Gramicidin and Tyrocidine

Dubos, a graduate of the French National Institute of Agronomy in Paris, emigrated to the U.S. in 1924. Among the passengers on his ship was Selman A. Waksman, professor of microbiology at Rutgers University, and the two quickly struck up an acquaintanceship. By the time the ship had docked the young Frenchman had decided to take courses under Dr. Waksman. The problem that Waksman assigned to him was how bacteria act in decomposing cellulose. More than a ton of leaves, brush and other cellulose-containing material falls on each acre of woodland annually, and the question was how the saprophytes decomposed this tough, fibrous substance. Dubos worked nearly three years on the problem and identified certain bacteria that produced specific enzymes which digested the cellulose.

O. T. Avery at the Rockefeller Institute heard of Dubos' work and was immediately interested. Avery had been deep in a study of the microbe which causes pneumonia, a bacterium of the globular or coccus form. This parasite was peculiar in its possession of a capsule of resistant material. The capsule protected the pneumococcus from the white cells of the bloodstream; it was Dr. Avery's idea that if some means could be devised to dissolve it, the exposed parasites would fall an easy prey to the blood cells. "I am sure that in the soil there is an organism producing the enzyme you want," asserted Dr. Dubos, and it was this prospect that brought him to the Rockefeller Institute in 1927. By 1929 Dubos had found the enzyme. When the capsular material was separated from the cells of the pneumococci and the enzyme was added to a mess of this material, the latter was quickly dissolved. Further experiments showed that the enzyme would work in the animal body as well as in the test tube, and soon a series of papers reported the control of pneumonia in mice, rabbits and monkeys by injections of this substance.

Another problem under investigation at this time was the measurement of creatine in the blood and other body fluids. Dubos turned again to his soil organisms, and found among them a species which produced an enzyme that attacked the creatine molecule. From the breakdown products the amount of creatine in a cubic centimeter of blood was determined.

"These results led me to think that there might be an enzyme which would attack a whole bacterium and destroy it, just as the enzymes had attacked the creatine and the capsular material," says Dr. Dubos. "I selected the staphylococcus for these tests. I took samples of soil and sewer water, cultured them in a broth of nutrients, separated the various organisms that developed, and then cultured each in a vessel. The next step was to add an inoculation of staphylococcus to each culture. It wasn't long before we observed that in one vessel the staph had disappeared. The organism which had this effect was a saprophytic bacterium

known as Bacillus brevis Watching through the microscope, we saw the rod-like bacillus attach itself to the globular staphylococcus, and presently the coccus dissolved before our eyes."

Dr. Dubos assumed that the bacillus released an enzyme which digested the staphylococcus, but he found that the material was not an enzyme It turned out to be a substance which poisoned the staphylococcus. Then the native enzymes within the coccus digested the dead cell.

The experimenters now turned to mice. Dr. Dubos infected them with various disease agents, and injected a shot of the extract B. brevis into each mouse. He noticed a systematic selectivity in the effect. Bacteria are classified according to their response to a staining technique devised some 60 years ago by the Danish biologist Hans Christian Gram. Some absorb Gram's stain and show a marked change in coloration, and these are called gram-positive bacteria; others do not retain the stain, and are called gram-negative. The orderly result that Dr. Dubos observed among his mice was this: Those infected with gram-positive bacteria, such as staphylococcus, streptococcus and pneumococcus, usually got well; those infected with gram-negative bacteria, such as the typhoid fever and colon bacilli, uniformly died despite the injection. Because of this specificity of effect in accordance with Gram's stain, Dubos named the new-found substance gramicidin.

A chemical purification was undertaken in collaboration with R. D. Hotchkiss of the Institute. It was found that the material was not a pure substance but a mixture of two antibiotics and some impurities. The more potent fraction constituted about 20 per cent of the mixture, and for it Dr. Dubos retained the name gramicidin. The other antibiotic, about 60 per cent of the mixture, was given the name tyrocidine. And the mixture itself Dr. Dubos chose to call tyrothricin. Pasteur's first assistant Duclaux had studied certain bacteria in cheese which caused the death of other bacteria, and to them he had given the name tyrothrix, meaning cheese rod. "It was in recognition of Duclaux's earlier work that I named the new-found materials tyrothricin and tyrocidine," says Dr. Dubos. Dubos and Hotchkiss reduced both gramicidin and tyrocidine to crystalline powders, and this was the first time that an antibiotic had been obtained in chemically pure form.

As the experiments were extended to rabbits, both gramicidin and tyrocidine proved to be toxic. This toxicity had not shown up in the mouse experiments, because these small animals were injected intraperitoneally; that is, the antibiotic was introduced into the abdominal cavity occupied by the digestive tract and had not got into the mouse's bloodstream. In rabbits the traditional point of entry is a vein of the ear, and when gramicidin was injected here it entered the circulation and attacked the blood cells. Experiments with dogs confirmed this hemolytic effect, and it was recognized that neither gramicidin nor tyrocidine should be introduced into the human body Their use therefore has been restricted to external applications. in wet dressings on sores and infected wounds, in salves and bandages, in nose drops and lozenges. Veterinarians have found them valuable in the treatment of infectious diseases in animals.

In the summer of 1939 Dr. Dubos gave an account of his experiments to the International Congress of Microbiology in New York. Among those who sought him out at the close of the address was a quiet, gray-haired Englishman who introduced himself as Alexander Fleming. Dubos vaguely remembered that some years before Fleming had published a paper reporting the antibiotic action of a substance produced by a mold.

Penicillin

Dr. Fleming was a bacteriologist at St. Mary's Hospital in London. In 1939 his discovery of penicillin was already 11 years old. Scarcely anyone outside a small circle of English bacteriologists remembered it.

The discovery was pure accident. Fleming had grown staphylococci in a culture plate and had left the plate uncovered. Some days later he observed a tiny spot of contamination where some airborne organism had chanced to land and grow. Such accidents are not uncommon in bacteriological laboratories, and the usual procedure is to scrap the contaminated plate and start a new culture. Still Dr. Fleming examined his unbidden visitor carefully. He noticed that it was a tiny fungus of the type that grows on bread, cheese and other foods as well as in the soil, and he recognized it as one of the numerous brushlike species known as penicillia.

The curious feature of the contamination was the transparent circle that surrounded the bit of mold like a halo. Under a microscope Fleming could see that this encircling area was completely clear. Not a single staphylococcus remained within it, although outside it they multiplied in teeming millions. Apparently the mold exuded some substance that brought death to the staphylococci. In June of 1929 Fleming published his results in the British *Journal of Experimental Pathology*, suggesting that penicillin "may be an efficient antiseptic for application to, or injection into, areas infested with penicillin-sensitive microbes."

In his paper Dr. Fleming described the source of his penicillin as "a certain type of Penicillium." It was not until 1932, when a specimen of the mold was sent to Charles Thom, chief mycologist of the United States Department of Agriculture, that the species was identified as Penicillium notatum.

Fleming never obtained a concentrate of penicillin. All he got was the clear liquor that he filtered from the broth in which the mold grew. Chemists tried to isolate the antibiotic, it proved elusive, and finally the prospect ceased to interest anyone but Alexander Fleming. For 10 years he patiently kept his original mold alive, and thus he was able to supply cultures of it when at last a team of workers appeared ready to carry the research forward.

The team was organized by Howard Florey, an Australian who had come to England on a Rhodes scholarship and had been appointed professor of pathology at Oxford University in 1935. The sort of pathology that interested him called for research, and Florey persuaded Ernst Chain, a German refugee biochemist then at Cambridge University, to join him at Oxford. These two formed the nucleus of the group which beginning in 1938 eventually separated penicillin from its culture broth and reduced it to a stable brown powder, devised a quick quantitative test for determining its presence, and made the first trials on animals. The brown powder proved nontoxic and so powerful in antibiosis that one part in a solution of 12 million was able to inhibit the deadly hemolytic streptococci. By 1941 sufficient penicillin had been isolated for trials on human patients. The record was one of almost unbroken triumph over infection.

The U.S. had begun to look into the possibilities of penicillin, and in 1941 Dr Florey brought over cultures of Fleming's mold and visited a number of American laboratories. The urgent needs of wartime medicine stimulated the U.S. and British governments to subsidize penicillin research on an unprecedented scale. The laboratories of pharmaceutical houses, research institutes, universities and government joined forces. An important center in this teamwork was the Northern Regional Research Laboratory of the U.S. Department of Agriculture at Peoria, Ill. Here mycologists discovered that a nutrient of cornsteeping liquor increased the yield of penicillin from Penicillium notatum. This was a big step forward, for the liquor, which is washed out of corn in making cornstarch, is abundant and cheap.

Meanwhile efforts were made to find more prolific strains of mold, and every available variety of Penicillium was tested for yield. In the summer of 1943 the Peoria group found a mold growing on a cantaloupe which in an enriched medium exuded about 200 units of penicillin per cubic centimeter of culture

medium. This was 100 times the 1941 yield of the original Fleming mold. The new find was identified as Penicillium chrysogenum, a near relative of the notatum species, and soon drug houses all over the country were growing the cantaloupe mold in their vats by the ton.

Presently the geneticists lent their knowledge and skills to this community of effort. Late in 1944 a group at the Carnegie Institution's Department of Genetics subjected a culture of Penicillium chrysogenum to bombardment with X-rays, a familiar technique for inducing genic changes in an organism. Most of the mold cells did not recover from this violent treatment, but certain spores survived and on cultivation some produced a mold that yielded 400 to 500 units of penicillin per c.c. A little later geneticists at the University of Wisconsin used ultraviolet rays in much the same way, and obtained a mutant that produced 800 to 1,000 units per c c. Most of the penicillin in current production comes from descendants of this Wisconsin mold. A unit of penicillin, by the way, is the minimum amount that, dissolved in 50 cubic centimeters of meat-extract broth, will stop the growth of Staphylococcus aureus. It is about one 60 millionth of a gram!

There are some 50 types of penicillin. Each has the same basic structure, but differs from its brother molecules by a distinctive side chain of atoms. Only four of the types have been produced in large quantities, and they are designated as G, F, X, and K. The most satisfactory for medicinal use is G, and practically all American manufacturers are concentrating on its production, which is easily accomplished by feeding the mold with phenylacetic acid. The K type is very unstable and quickly disappears from the bloodstream; F is difficult to purify; and X, though potent, is difficult to produce.

Despite the feverish search for new antibiotics, penicillin remains the antibiotic in greatest use. It is the first choice for treating a wide range of diseases caused by gram-positive bacteria, and in addition it is the most potent drug yet found against that notorious member of the gram-negative tribe, the gonococcus. Indeed, the most dramatic success in the annals of chemotherapy is the cure of gonorrhea by a single injection of 17,000 units of penicillin. Almost as spectacular is its antagonism for the spirochete of syphilis.

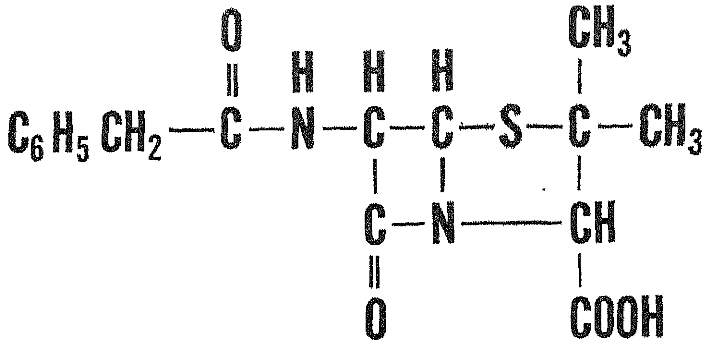
Streptomycin

Penicillin was still powerless against most of the gram-negative bacteria. Who would be the first to find a chemical weapon against these noxious agents of disease? Unfortunately there are not many clues to guide one in such a search. There is no characteristic molecule to seek out, for the antibiotics which have

RENE J. DUBOS of the Rockefeller Institute for Medical Research stimulated much work in antibiotics by his discovery of gramicidin and tyrocidine.

ALEXANDER FLEMING, discoverer of penicillin, is progenitor of modern antibiotic research. It was Pasteur, however, who first observed antibiosis.

G



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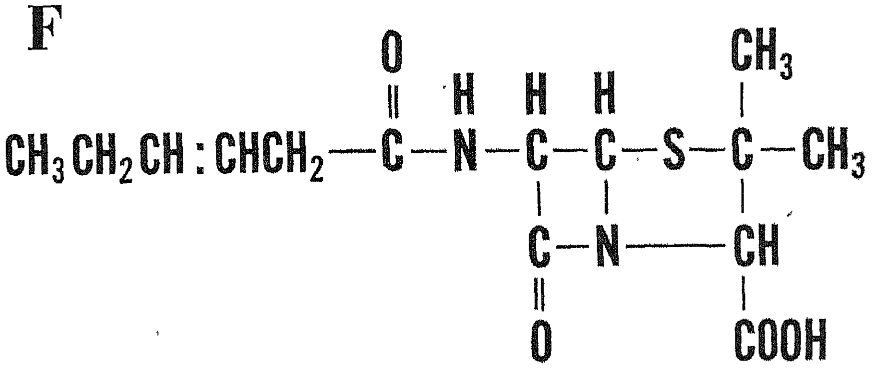

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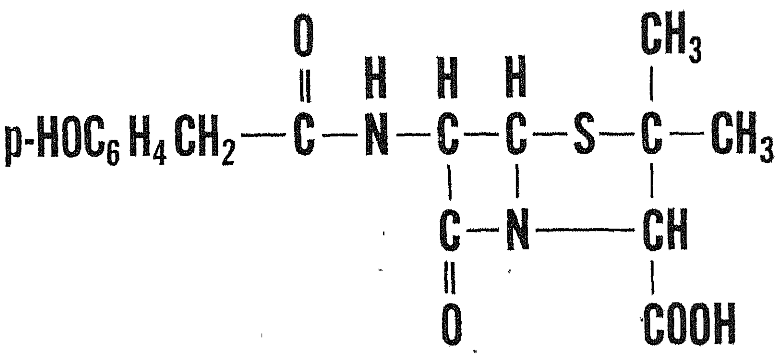

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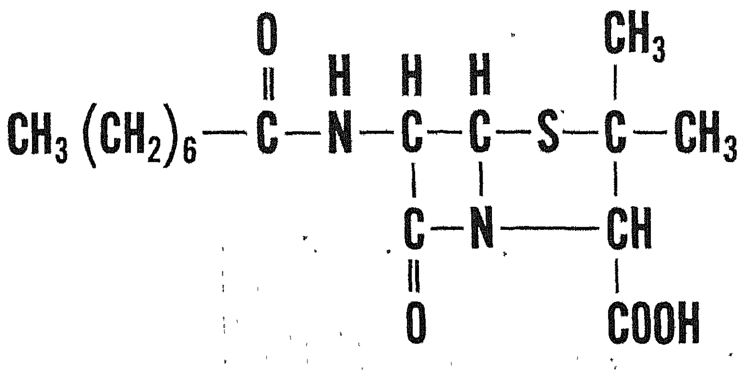


MOLECULAR STRUCTURE of penicillin varies with its types. The fundamental structure (*red area*), however, remains the same. There are some 50 types of penicillin but only types G, F, X and K have been produced in quantity. Of them G is best from the clinical and manufacturing standpoint.

been chemically analyzed are of many contrasting structures The procedure thus becomes the chemical analogue of searching for the needle in the haystack, without knowing what the needle looks like. It is a matter of accumulating as many specimens of soil as one can handle, testing every microorganism that shows up in the cultures, and hoping that out of 1,000 or so one specimen may prove useful. This was the method that in 1944 led to the discovery of streptomycin.

For more than 25 years Selman A. Waksman had been studying soil organisms, but his primary purpose during most of this research was to find their role in soil processes and in humus formation In the New Jersey State Agricultural Experiment Station at Rutgers University Dr. Waksman had isolated thousands of microbes of different genera and species, but not until 1939 did he begin to study them from the point of view of their possible service to medicine. It was the discovery of gramicidin by his former pupil, Dubos, that turned Waksman's interest in this direction, and from then on the search for new antibiotics became the principal concern of his laboratory in New Brunswick. Only a few miles distant at Rahway were the laboratories of Merck and Company, Inc., and the chemists and biologists there collaborated with Waksman in the multitudinous tests which soon got under way.

"We examined some 10,000 cultures," relates Dr. Waksman, "obtained antibiotic substances from about 1,000 of them, found some 100 specimens that gave promise of being medically useful, and finally narrowed the chase to 10 that seemed worth following closely." The first to be studied was the antibiotic known as streptothricin. When discovered in 1942 it seemed highly promising, but later tests with animals showed it to be too toxic for medical use. Streptothricin was not without value, however, for it led to the discovery of streptomycin.

Streptomycin gets its name from Streptomyces griseus, the organism which produces it. This is a different kind of organism from the bacterium that produces gramicidin and the mold that makes penicillin. It is an actinomycete, a family of which numerous species have been identified. Actinomycetes grow as branching rods that sometimes form filaments, but they are usually smaller than the filaments of Penicillium, being of the dimensions that characterize bacteria Curiously Streptomyces griseus had been isolated by Waksman in 1915, long before he was interested in antibiotics.

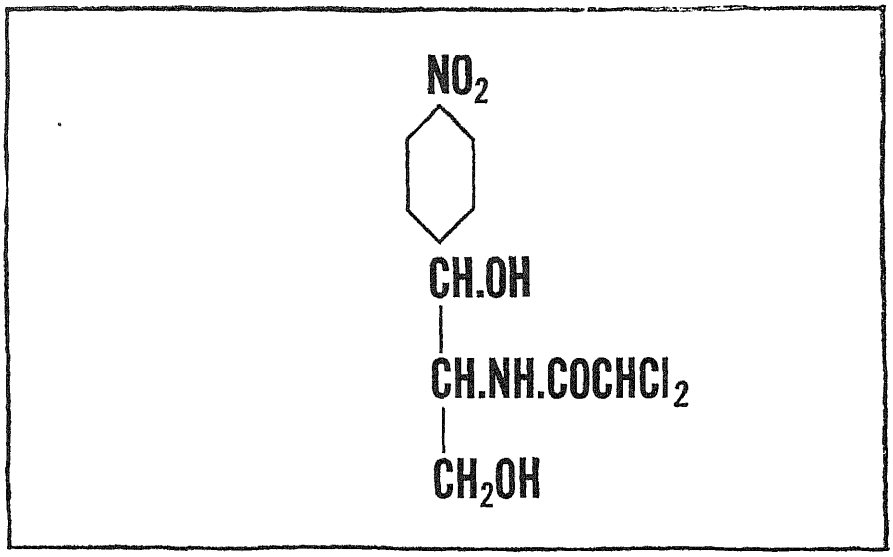
Among the bacteria that fell prey to streptomycin were those which cause tularemia, certain urinary-tract infections, and a form of meningitis in chil-

dren. But the result that attracted the greatest attention was its effect on Mycobacterium tuberculosis. Penicillin had never slowed the course of the "white plague," although its agent is a gram-positive bacterium. Mycobacterium tuberculosis is an exceedingly stubborn gram-positive of the type known as acid-fast. The fact that streptomycin interfered drastically with its mode of life was highly important news. Physicians in all parts of the U.S. began to call for the new drug, and today more than 70 per cent of the current monthly output of six and a half tons of streptomycin goes to tuberculosis patients.

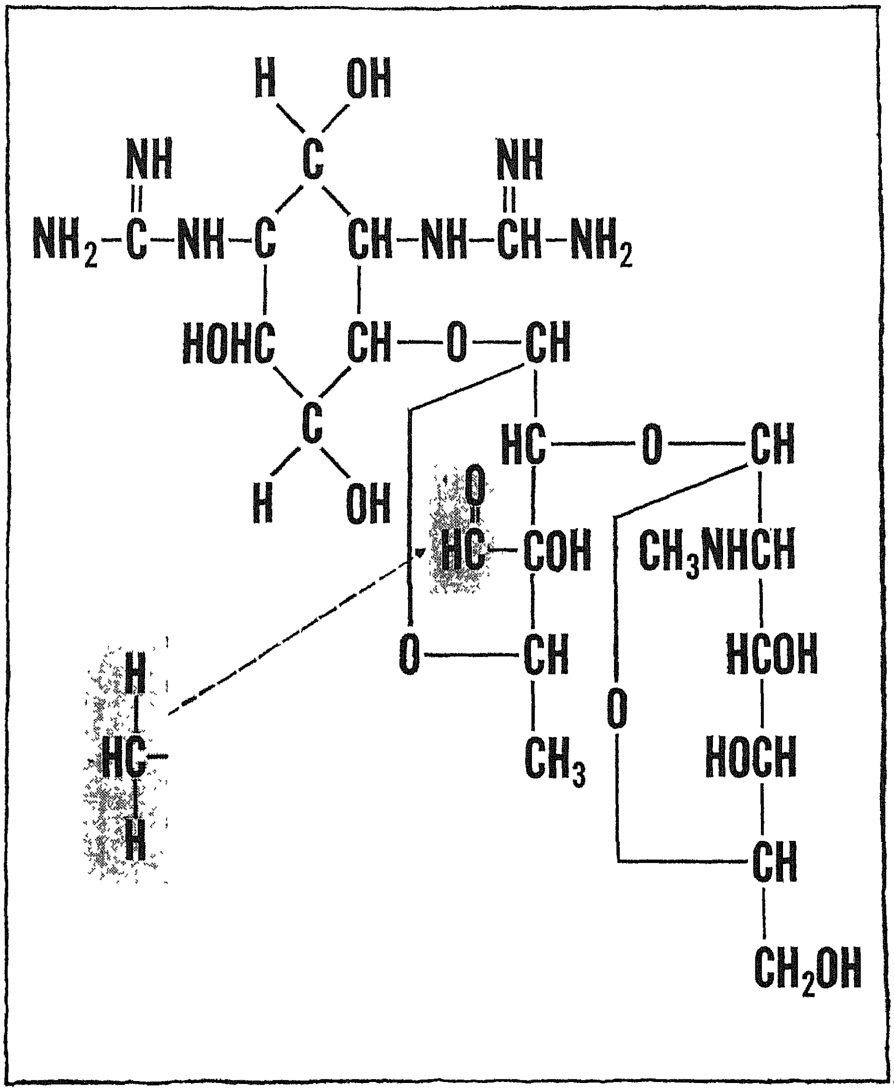
Streptomycin has its drawbacks. The treatment of a disease with streptomycin usually requires a relatively long period of medication. A serious tuberculous condition may require daily shots for three or four months The side effects on the patient, which in the case of penicillin are rarely more than a mild allergic reaction, are sometimes severe and occasionally involve damage to the kidneys. Streptomycin also has an effect on the auditory nerve which causes dizziness, sometimes imposes temporary deafness, and in a few recorded instances had left the patient permanently deaf. These toxic effects limit the use of streptomycin, and there have been numerous attempts to moderate them. Merck chemists have accomplished a slight modification of the streptomycin molecule by slipping two hydrogen atoms into a certain part of the structure to form what is known as dihydrostreptomycin. Ralph Tompsett and a group at the Cornell University Medical College have shown that this dihydrostreptomycin is less toxic than the unaltered molecule, though no less potent against bacteria.

Unhappily bacteria often develop such a high resistance to streptomycin that continuation of the treatment becomes useless. As Walsh McDermott of Cornell phrases it: "The emergence of predominance of drug-resisting microorganisms occurs to an infinitely greater degree with streptomycin than with any other antibacterial drug now available. With penicillin, chloramphenicol [Chloromycetin] and aureomycin, bacterial resistance is a rarity in clinical practice; with streptomycin it is the rule."

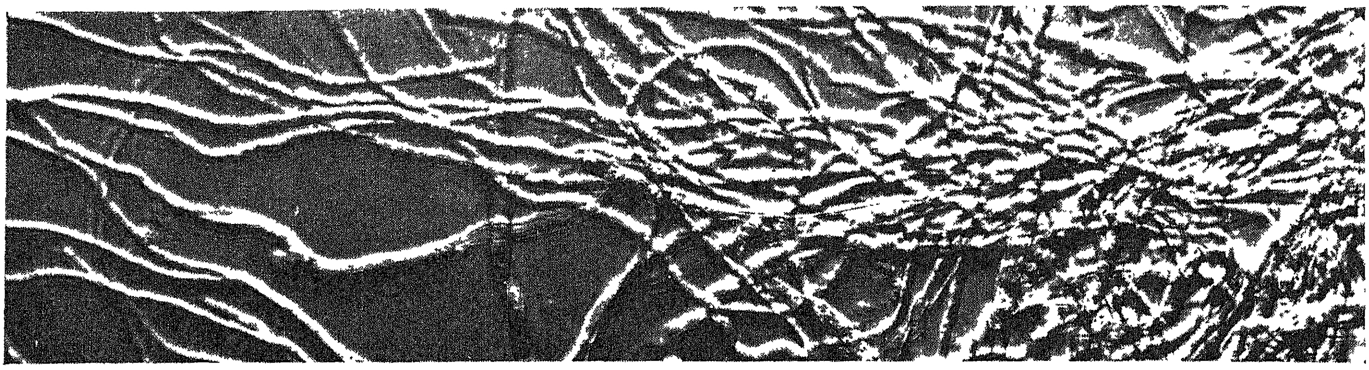
This bacterial resistance stimulated the laboratory where streptomycin was discovered to new efforts. Within the past three years the group at Rutgers has investigated thousands of organisms to find a safe antibiotic which is as potent as streptomycin but not so provocative of the bacteria's resistance. The first fruits of this search came in March when Waksman and H. A. Lechevalier published their observations of a substance derived from another actinomycete, Streptomyces fradiae, which they have named neomycin. In these tests most of



STRUCTURE OF CHLOROMYCETIN is unusual in that it contains a nitrobenzene group, which heretofore has been considered inimical to biological processes. Chloromycetin and aureomycin both contain chlorine and nitrogen. Name Chloromycetin is derived from chlorine and actinomycete.



STRUCTURE OF STREPTOMYCIN has been altered to produce dihydrostreptomycin. The structure of streptomycin is at the right. In dihydrostreptomycin one oxygen atom is replaced by two hydrogen atoms (*left*). This change apparently makes the variation less toxic than its progenitor.



PENICILLIUM CHRYSOGENUM, which because of its greater productivity has generally replaced Penicillium notatum in the making of penicillin, grows in fine filaments. These are shown in photomicrograph above.

the bacteria that are vulnerable to streptomycin showed an equal or even greater sensitivity to neomycin. Moreover, those that had become strongly resistant to streptomycin were halted in their growth by neomycin. Later studies have shown that after 120 days' exposure colonies of tubercle bacilli were still sensitive to neomycin, 60 to 70 days' exposure of the same parasites to equal concentrations of streptomycin invariably resulted in deep-rooted resistance.

By June only a few grams of neomycin had been obtained. Pilot plants now operating will turn out larger quantities and fractionate the present concentrate, which appears to be a mixture. Dr. Waksman thinks there are at least two neomycins, and clinical testing of the substances must await their separation and crystallization.

Chloromycetin

The scene now shifts to Yale University, where a microbiologist had cultured soils brought from many countries to see what new material he might find. The microbiologist was Paul R. Burkholder, who was working under an arrangement with the pharmaceutical firm of Parke, Davis and Company. As rapidly as Burkholder found organisms that showed any promise of medical utility, he sent cultures to the pharmaceutical research laboratories in Detroit for further testing. One day in the summer of 1947 he discovered that an actinomycete he had recovered from a soil sample collected in a mulched field near Caracas, Venezuela, gave off a substance that halted the growth of half a dozen bacterial species. Burkholder's tests were extended to other species in Detroit, and they showed that both gram-positive and gram-negative bacteria were susceptible. The name Streptomyces venezuelae was given to the actinomycete, in recognition of the country of its origin; the antibiotic crystallized out of its culture medium was named Chloromycetin, since it contained chlorine and was produced by an actinomycete.

Experiments with chick embryos made by I. W. McLean of Parke, Davis suggested that the new antibiotic might be effective against diseases of the typhus type, and on the strength of this hint Chloromycetin was sent to the Army Medical Center in Washington. There J. E. Smadel and E. B. Jackson tested it on the agents of epidemic typhus and scrub typhus, and obtained complete inactivation. What made the Washington results so thrilling was not the fact that two additional species had been added to the list of vulnerable microbes, but that the two were of an order of microbial life different from those which had previously yielded to penicillin and streptomycin. The typhus agent is not a bacterium, but a microbe of the order known as Rickettsia. Here at last, it seemed, was an antibiotic that might prove specific for the whole group of rickettsial diseases.

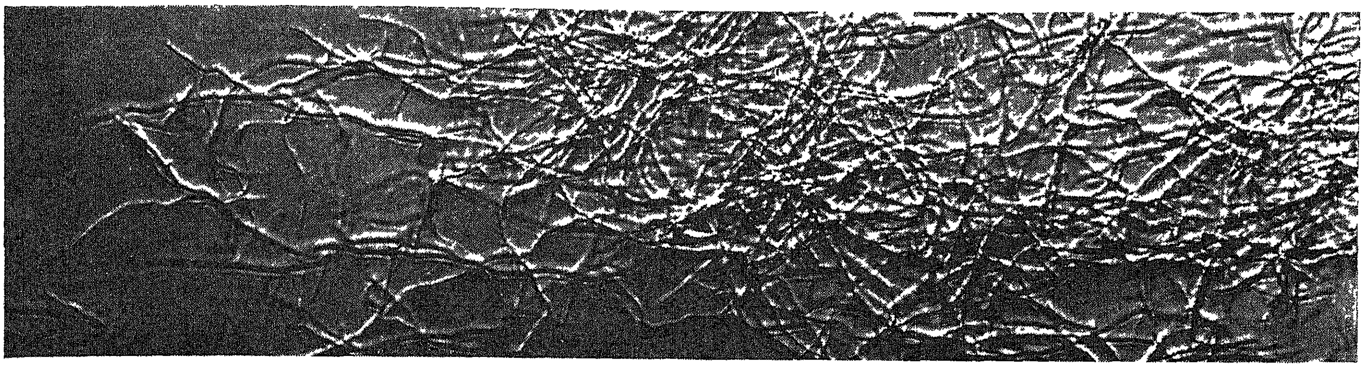
The first opportunity to try the material on human rickettsial infections came toward the end of 1947 with a call from public health officials in Bolivia, where epidemic typhus had broken out in the Department of La Paz. Eugene Payne of Parke, Davis gathered together all the Chloromycetin he could lay hands on and flew to Bolivia with it. Fourteen of the 50 patients for whom there was no Chloromycetin died; every one of the 22 patients treated with the antibiotic got well. Dr. Smadel had a hand in the next clinical trial, which was made at Kuala Lumpur in Malaya, where scrub typhus was active. Twenty-five proved cases were treated, and each made a rapid recovery with no complications; among 12 untreated cases, the illness was long, one patient died, and two suffered serious complications. Since these early demonstrations Chloromycetin has rescued many other victims of rickettsial as well as bacterial infections under less dramatic circumstances but with equally successful results. It was the first antibiotic to prove effective against typhoid fever. Since the early clinical tests, the range of infections susceptible to Chloromycetin has been further extended to include certain virus diseases and many invasions by bacteria, both gram-positive and negative. A hindrance to its widespread use was the fact that the producers were able to obtain only limited supplies by culturing Streptomyces venezuelae. This handicap is now being overcome by chemical synthesis.

Chloromycetin, however, is not the first antibiotic to be made artificially. Penicillin was synthesized in 1947 through the joint efforts of chemists in the U.S. and England, but the process is so indirect, so slow and expensive that it cannot compete with the fermentation of the mold. In the case of Chloromycetin the chemists were fortunate in having a simpler and less eccentric molecule to reconstruct, and the synthesis was accomplished last year at the Parke, Davis laboratories by Harry M. Brooks, Jr., Quentin R. Bartz, John Controulis and Mildred C. Rebstock.

Aureomycin

While the pharmaceutical chemists in Detroit elucidated the structure of Chloromycetin and synthesized it, another group of researchers at the Lederle Laboratories in Pearl River, N.Y., discovered, tested and produced aureomycin. This antibiotic gets its name from the organism that manufactures it, Streptomyces aureofaciens, another member of the numerous family of actinomycetes. Benjamin M. Duggar and his associates at Lederle examined thousands of microscopic fungi before they focused their efforts on the hitherto-undescribed species which tinctured its culture broth with the golden antibiotic This new microbe-killer, which was announced in a series of papers presented to the New York Academy of Sciences last summer, is already in mass production.

An account of early experiences with aureomycin in the treatment of disease has already appeared in this magazine (SCIENTIFIC AMERICAN, April). While it cures many infections that also yield to penicillin and streptomycin, its antagonism for the rickettsiae and certain viruses has attracted more attention. The early supply of aureomycin available to physicians was limited; consequently they concentrated their use of it on those diseases that are beyond the reach of the more abundant drugs. Aureomycin gives remarkable results in the treatment of undulant fever, a bacterial infection, and recent reports indicate that it is ef-



STREPTOMYCES GRISEUS, the organism that produces the antibiotic streptomycin, has even finer filaments than Penicillium chrysogenum. Penicillium is a mold; Streptomyces is classified as an actinomycete.

fective against amoebic dysentery, a protozoal infection, and against shingles, a virus infection. Although aureomycin requires dosages in higher concentrations than penicillin, it imposes few and only minor side effects on the patient. In lack of toxicity and of bacterial resistance, aureomycin and Chloromycetin appear to be close rivals. Both are preferably administered by mouth, whereas streptomycin must be injected. If penicillin is given orally the dose must be five times greater than the injected dose.

Harold Raistrick, professor of biochemistry at the University of London, published in the British scientific journal *Nature* last January an assessment of the probable comparative value of the four antibiotics now used medicinally. "In the treatment of most gram-positive bacterial infections, the supreme position of penicillin remains unchanged," said Dr. Raistrick. "Streptomycin appears to hold a similar though less exalted position in the treatment of many tuberculous infections; but it seems probable that aureomycin may displace streptomycin in the treatment of many gram-negative infections, particularly of the urinary tract, because of the unquestioned advantage it possesses that bacteria do not become resistant to it *in vivo* as they often do to streptomycin. In the treatment of viral and rickettsial diseases, both Chloromycetin and aureomycin offer considerable grounds for hope in infections which have so far proved very resistant to chemotherapeutic agents."

Gaps in the Defense

Antibiotics have scored their greatest triumphs against bacteria, but there remain a number of bacterial diseases yet to be conquered. Although massive daily doses of penicillin have cured certain staphylococcal and streptococcal infections of the heart, there are cases that resist every known drug. Certain infections of the urinary tract caused by the bacteria proteus and pyocyaneus, meningitis caused by the pneumococcus, and other such infections still need more effective antibiotic treatment.

It is among the virus diseases that the most serious gaps remain, for viruses account for some of the most crippling and widespread invasions known to the human body: infantile paralysis, influenza, smallpox, yellow fever and many other diseases. Although effective vaccines have been developed against smallpox and yellow fever, there is still no drug to halt these infections once they have gained a foothold. It is true that Chloromycetin and aureomycin have scored brilliant successes against several disorders which are loosely rated as of viral origin: notably psittacosis, the venereal infection lymphogranuloma venereum, and atypical pneumonia. But atypical pneumonia is only asssumed to be a virus disease—its agent has never been characterized; and psittacosis and lymphogranuloma venereum are caused by relatively large agents on the borderline between viruses and rickettsiae.

Several laboratories are concentrating on the search for antibiotics against viruses. The Merck Institute for Therapeutic Research recently installed Richard E. Shope in a new building especially designed and completely equipped for the investigation of these tiny disease organisms. A year ago, at the Rockefeller Institute for Medical Research, Dr. Shope found in a filtrate of Penicillium funiculosum a substance that protected mice against the virus of swine influenza. Swine influenza is not the same as human influenza, but this finding in animal pathology may provide clues to human pathology.

Another center of research in the virus field is the New York Botanical Garden. Here Igor N. Asheshov and others are investigating bacteriophage. The phage is a virus which destroys bacteria, and a very useful virus it is from the human point of view. Since it is harmless to man, physicians sometimes use it clinically to combat staphylococcal and streptococcal infections. Dr. Asheshov is not interested in the phage as a therapeutic agent but as a representative of the virus type of microbe. The study of this virus which attacks bacteria may shed light on the viruses which attack men—as in poliomyelitis. The American Foundation for Infantile Paralysis is supporting the study, and already Dr. Asheshov and his co-workers have discovered two substances produced by a fungus of the Aspergillus group which stop phage action. One of these substances is effective against the phage that combats staphylococcus, the other against that which inhibits streptococcus.

"It is a long way from the bacteria's disease of phage to mankind's disease of infantile paralysis," grants W. J. Robbins, who is in general charge of the research at the Botanical Garden, "and we are not so naive as to believe that our search will directly turn up an antibiotic against poliomyelitis. But the study may disclose new knowledge of viruses which will open fresh leads toward an understanding of the polio virus. And we hope that out of all these efforts there may eventually come the discovery by someone of a chemical compound that will cure infantile paralysis."

Bacterial Resistance

As early as 1940, Florey and his associates noticed that after prolonged exposure to penicillin bacteria often developed the ability to grow in spite of the drug. Since then many investigators have explored the phenomenon of bacterial resistance. An interesting contribution to our knowledge of this subject was made at the University of Chicago in 1947 by C. Philip Miller and Marjorie Bohnhoff. They cultured the meningococcus in a broth containing a solution of penicillin too dilute to inhibit the bacterial growth, and increased the concentration of the penicillin at periodic intervals. After 147 transfers had been made the bacteria were still growing, though the medium then contained 5,000 units of penicillin per c.c. This concentration ordinarily would stop growth completely. When transferred to penicillin-free broths, however, the bacteria gradually lost their resistance and once more became susceptible to the drug.

Streptomycin not only invokes resistance to a greater degree than the other antibiotics, but once acquired, the resistance appears to be a permanent property of the bacterial strain. Drs. Miller and Bohnhoff found that meningococci produced different types of resistant variants after continued exposure to strep-

tomycin. One type would not grow at all unless the broth contained at least five micrograms of streptomycin per c.c Moreover, when the bacteria of this strain were injected into mice they proved to be harmless unless streptomycin also was injected into the animal. Thus one bacterium's poison had become another bacterium's meat.

These changes in the response of a microbe or a microbial population to the presence of a chemical compound may be the result of the acquisition of a new enzyme system or other metabolic resource which permits the organism to survive in spite of, or with the assistance of, the antibiotic. Or the changes may be inherent in certain bacterial individuals as a result of genic mutation

The mutation theory is strongly supported by the experiments of M. Demerec at the Carnegie Institution's laboratory at Cold Spring Harbor, N.Y. He has subjected the same species of bacteria to corresponding concentrations of penicillin, streptomycin and aureomycin, and noted the rates at which resistance builds up, and the changes that occur when exposure to the antibiotic is discontinued. From these studies Dr Demerec is convinced that resistance is controlled by mutational changes in the bacterial cell, and that these changes involve several genes. His data indicate that in the average bacterial colony only about one individual out of every 10 million is a resistant mutant. The bacterial population in any infectious disease comprises so many billions that even this microscopic fraction provides several thousand resistant mutants. Since the antibiotic does not affect them, they proceed to multiply while the billions of susceptible individuals die away; soon the population is predominantly resistant.

"The most effective way, theoretically, of preventing the origin of resistant strains of bacteria," says Dr. Demerec, "is the use of a mixture of two antibiotics, when such are available, that affect the same parasites but are independent in their actions. If such a mixture is used, then only bacteria that are resistant to both antibiotics can survive the treatment and form first-step resistant strains. Such bacteria would be exceedingly rare. For example, if first-step resistant bacteria for each of two different antibiotics should be found in a large bacterial population with a frequency of one in 10 million, then the expected frequency of bacteria resistant to both antibiotics would be one in 100 million million."

Mode of Action

How a bacterium resists the action of the antibiotic must depend on what that action is. Is it bactericidal, *i.e.*, does the antibiotic kill the bacterium directly? Or is it bacteriostatic, a process which blocks growth and thus reduces the parasite to a state of stagnation, making it an easy prey for the white blood cells? Apparently both processes are at work, depending on the nature of the drug and its degree of concentration. The English bacteriologist L. F Garrod has made a comparative study of the action of penicillin and streptomycin and reported that streptomycin exerts a more immediate bactericidal effect, beginning, under favorable conditions, within one minute after contact.

Various studies have been made of the biochemistry of susceptible microbes in the presence of an antibiotic, to see what it is that the drug does. In the case of penicillin, the evidence indicates that the assimilation of glutamic acid by the bacterial cells is obstructed. In the case of streptomycin, the action similarly is one of interruption of the bacterial cell's metabolism, although the blockade here occurs in the respiratory process.

The site of this blockade by streptomycin was recently identified by W. W. Umbreit of the Merck Institute in a series of experiments with the colon bacillus. Dr. Umbreit was able to show that at one point in the chain of reactions which constitute the respiration of this bacterium, the compound oxalacetate reacts with various substances, and he demonstrated that the effect of streptomycin is to halt this step. If oxalacetate is not condensed, the microbe's metabolism is unable to proceed to its next step.

ACKNOWLEDGEMENT

The author wishes to thank the following scientists who generously cooperated in the preparation of this article: Igor N. Asheshov and W. J. Robbins of the New York Botanical Garden; Dean Burk of the National Cancer Institute; Paul R. Burkholder of Yale University; M. Demerec of the Carnegie Institution; Rene J. Dubos of the Rockefeller Institute for Medical Research; B. M. Duggar of the Lederle Laboratories, Perrin H. Long of Johns Hopkins Medical School; Walsh McDermott of Cornell University Medical College; Hans Molitor, Otto Grassle, Richard E. Shope, W. W. Umbreit, and Boyd Woodruff of Merck Institute for Therapeutic Research; Arthur L. Schade of Overly Biochemical Research Foundation, Leon A. Sweet of Parke, Davis and Company, Selman A. Waksman and Dale A. Harris of Rutgers University.

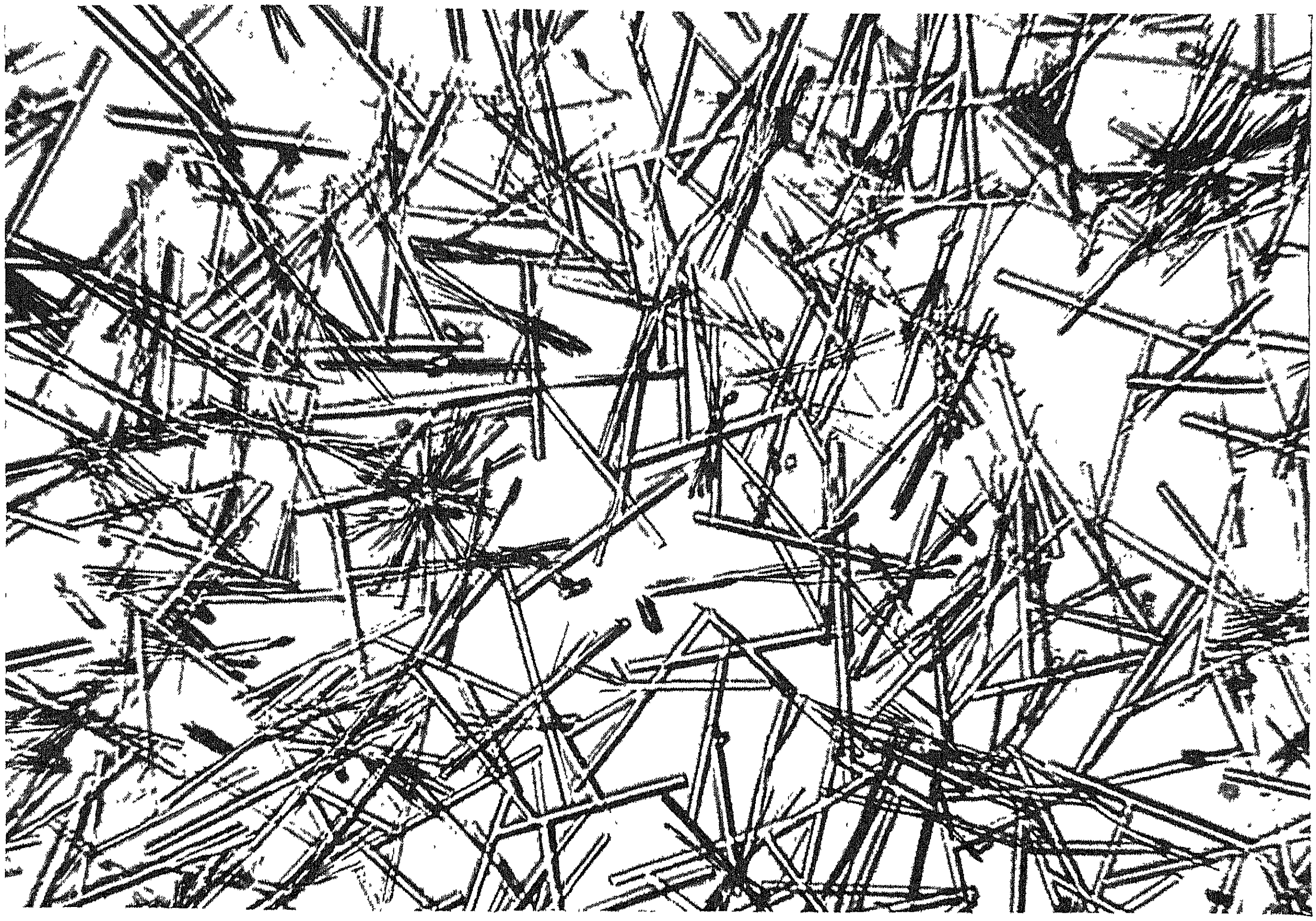
Reducing Toxicity

The object of antibiotic research may be reduced to a phrase: to make the compound more toxic for the parasites and less toxic to the human body which the parasites infest. There are any number of substances that are highly potent against bacteria, but, like gramicidin, they are too destructive of blood cells or too antagonistic to kidney or other tissue cells to be admitted to the bloodstream. Bacitracin was discovered in 1943 and widely hailed as an antibiotic, but the Food and Drug Administration has cleared it only as an antiseptic for the external treatment of wound and surgical infections Polymixin is a more recent discovery. Some trials of it have been made clinically on a few hopeless human cases of infection, but the drug effects are too severe to permit of general use. Yet a given quantity of polymixin can demolish gram-negative bacteria with a completeness and celerity provided by no other antibiotic Perrin H. Long and his associates at Johns Hopkins report that polymixin is twice as potent against bacteria as streptomycin, and in the case of certain organisms it is 80 times more effective.

Polymixin, bacitracin and gramicidin are related chemically, their molecules being of the type known as a polypeptide. Toxicity seems to be inherent in this type of molecule. It is significant also that these polypeptide antibiotics are produced by bacteria. Some researchers question whether it is worth-while to prospect bacteria further for useful antibiotics. The actinomycetes, with streptomycin, Chloromycetin and aureomycin already to their credit, are the microorganisms in greatest favor today—and there are many species in this group which are still to be tested for antibiotic production.

If the molecule is toxic because of its structure there is not much that one can do about it. But even if the molecule is inherently nontoxic there is the chance that it may pick up poisonous compounds from the medium, and that in extracting the antibiotic one may get this toxic contamination. Such admixtures are almost inevitable if the culture medium is of an unknown composition, as are most natural broths. There is a strong tendency, therefore, to develop synthetic culture media, that is, broths that are made of selected chemical compounds assembled in the laboratory. Instead of mixing beef extract or cornsteeping liquor or other natural nutrients into the broth, the synthetic experimenters are trying to determine precisely what pure chemical compounds the growing organisms need to produce antibiotics. When that is known, they expect to be able to control the production to a far greater extent than is presently possible.

George W. Gray was the author of Cosmic Rays, *which appeared in the March issue of this magazine.*



STREPTOMYCIN is isolated in crystals of streptomycin trihydrochloride-calcium chloride double salt. Recently a similar antibiotic, neomycin, was discovered in the same laboratory that produced streptomycin. Neomycin appears to be an improvement on streptomycin in that it is less likely to stimulate the resistance of bacteria.

PENICILLIN is isolated in crystals of its type G. Although it was discovered by Fleming in 1928, it was not isolated by Howard Florey and his associates until 1938.

CHLOROMYCETIN crystals have been reproduced synthetically. Penicillin has also been synthesized, but process does not lend itself to large-scale manufacture.

LEARNING TO THINK

Some psychologists have believed that human beings are born with certain powers of reason. The authors present the view that all such functions must first be learned

by Harry F. and Margaret Kuenne Harlow

HOW does an infant, born with only a few simple reactions, develop into an adult capable of rapid learning and the almost incredibly complex mental processes known as thinking? This is one of psychology's unsolved problems. Most modern explanations are not much more enlightening than those offered by 18th-century French and English philosophers, who suggested that the mind developed merely by the process of associating ideas or experiences with one another. Even the early philosophers realized that this was not a completely adequate explanation.

The speed and complexity of a human being's mental processes, and the intricacy of the nerve mechanisms that presumably underlie them, suggest that the brain is not simply a passive network of communications but develops some kind of organization that facilitates learning and thinking. Whether such organizing principles exist has been a matter of considerable dispute. At one extreme, some modern psychologists deny that they do and describe learning as a mere trial-and-error process—a blind fumbling about until a solution accidentally appears. At the other extreme, there are psychologists who hold that people learn through an innate insight that reveals relationships to them.

To investigate, and to reconcile if possible, these seemingly antagonistic positions, a series of studies of the learning process has been carried out at the University of Wisconsin. Some of these have been made with young children, but most of the research has been on monkeys.

For two basic reasons animals are particularly good subjects for the investigation of learning at a fundamental level. One is that it is possible to control their entire learning history: the psychologist knows the problems to which they have been exposed, the amount of training they have had on each, and the record of their performance. The other reason is that the animals' adaptive processes are more simple than those of human beings, especially during the first stages of the attack on a problem. Often the animal's reactions throw into clear relief certain mechanisms that operate more obscurely in man. Of course this is only a relative simplicity. All the higher mammals possess intricate nervous systems and can solve complex problems. Indeed, it is doubtful that man possesses any fundamental intellectual process, except true language, that is not also present in his more lowly biological brethren.

Tests of animal learning of the trial-and-error type have been made in innumerable laboratories. In the special tests devised for our experiments, we set out to determine whether monkeys could progress from trial-and-error learning to the ability to solve a problem immediately by insight.

One of the first experiments was a simple discrimination test. The monkeys were confronted with a small board on which lay two objects different in color, size and shape. If a monkey picked up the correct object, it was rewarded by finding raisins or peanuts underneath. The position of the objects was shifted on the board in an irregular manner from trial to trial, and the trials were continued until the monkey learned to choose the correct object. The unusual feature of the experiment was that the test was repeated many times, with several hundred different pairs of objects. In other words, instead of training a monkey to solve a single problem, as had been done in most previous psychological work of this kind, we trained the animal on many problems, all of the same general type, but with varying kinds of objects.

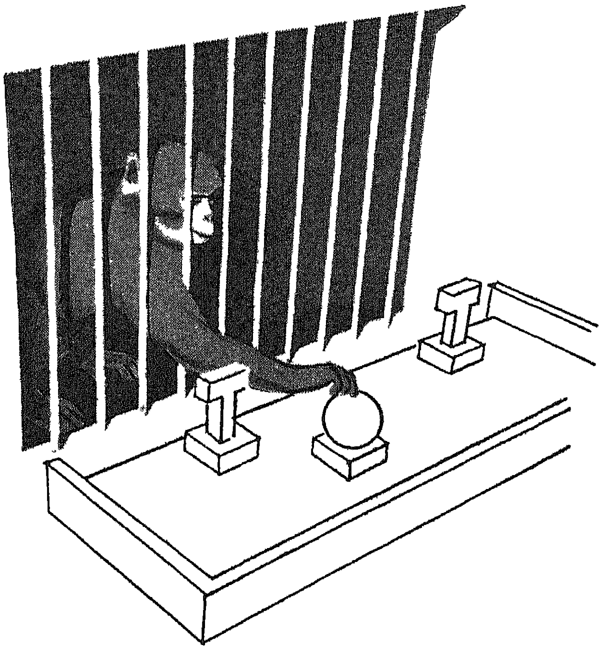
When the monkeys first faced this test, they learned by the slow, laborious, fumble-and-find process. But as a monkey solved problem after problem of the same basic kind, its behavior changed in a most dramatic way. It learned each new problem with progressively greater efficiency, until eventually the monkey showed perfect insight when faced with this particular kind of situation—it solved the problem in one trial. If it chose the correct object on the first trial, it rarely made an error on subsequent trials. If it chose the incorrect object on the first trial, it immediately shifted to the correct object, and subsequently responded almost perfectly.

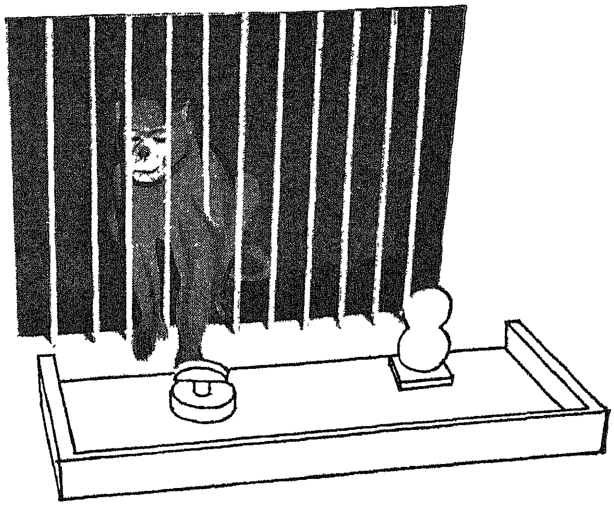
Thus the test appeared to demonstrate that trial-and-error and insight are but two different phases of one long continuous process. They are not different capacities, but merely represent the orderly development of a learning and thinking process.

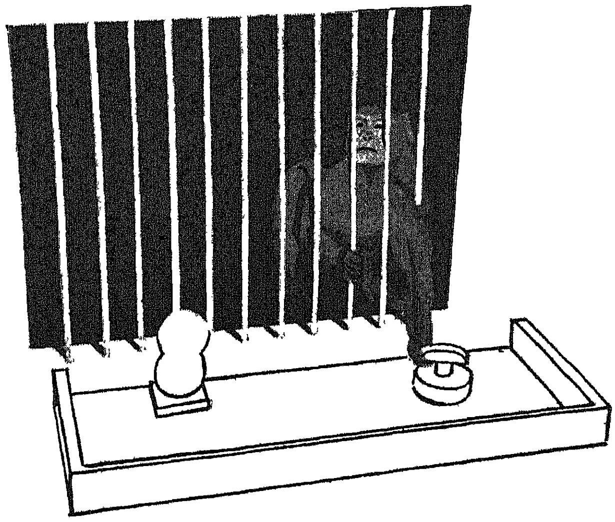
A LONG series of these discrimination problems was also run on a group of nursery-school children two to five years of age. Young children were chosen because they have a minimum of previous experience. The conditions in the children's tests were only slightly different from those for the monkeys: they were rewarded by finding brightly colored macaroni beads instead of raisins and peanuts. Most of the children, like the monkeys, made many errors in the early stages of the tests and only gradually learned to solve a problem in one trial. As a group the children learned more rapidly than the monkeys, but they made the same types of errors. And the "smartest" monkeys learned faster than the "dullest" children.

We have called this process of progressive learning the formation of a "learning set." The subject learns an organized set of habits that enables him to meet effectively each new problem of this particular kind. A single set would provide only limited aid in enabling an animal to adapt to an ever-changing environment. But a host of different learning sets may supply the raw material for human thinking.

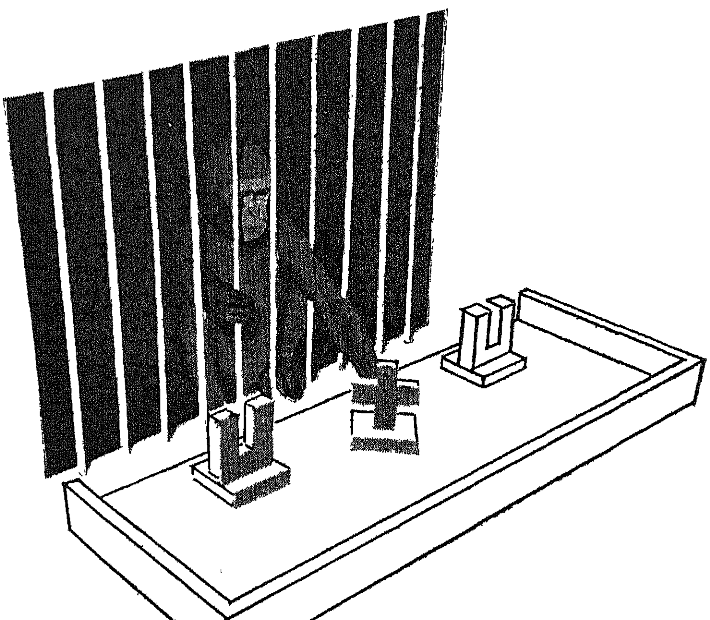
We have trained monkeys and children to solve problems much more complex than the ones thus far described. For instance, a deliberate attempt is made to confuse the subjects by reversing the conditions of the discrimination test. The previously correct object is no longer rewarded, and the previously incorrect object is always rewarded. When monkeys and children face this switch-over for the first time, they make many errors, persistently choosing the objects they had previously been trained to choose. Gradually, from problem to problem, the number of such errors decreases until finally the first reversal trial is followed by perfect performance. A single failure becomes the cue to the subject to shift his choice from the object which has been rewarded many times to the object

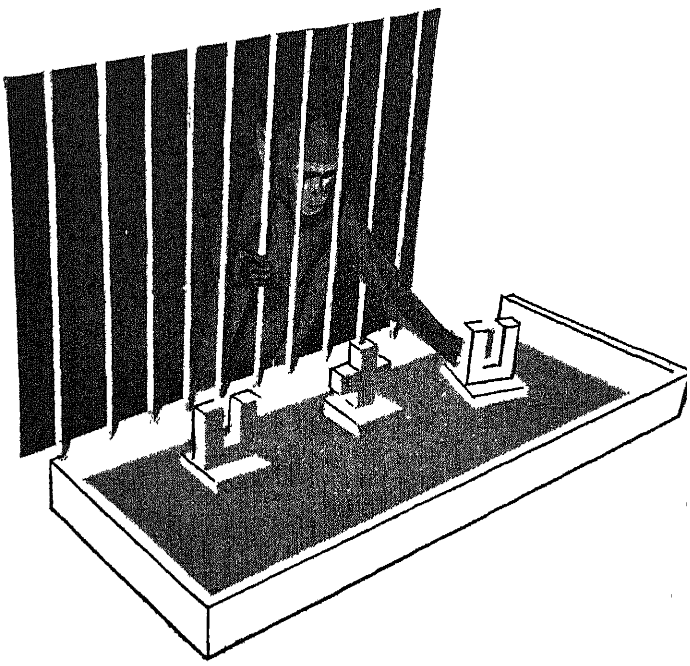






MONKEY EXPERIMENTS at the University of Wisconsin illustrate the process of learning. In the drawing at the upper right a monkey is confronted with two different objects. Under one of them is always a raisin or a peanut. In the drawing at the right the monkey has learned consistently to pick the same object. In the drawing above the monkey has learned consistently to choose one object which differs from two others. In the two drawings below the monkey has learned a much more complicated process. In the drawing at the lower left it has learned that when the board is of a certain color it must choose the object that is odd in shape. In the drawing at the lower right it has learned that when the board is of another color it must choose the object that is odd in color. In all these problems the monkey first learned to solve the problem by trial and error. Later it solved them immediately by understanding.





which has never been rewarded before. In this type of test children learn much more rapidly than monkeys.

A group of monkeys that had formed the discrimination-reversal learning set was later trained on a further refinement of the problem. This time the reward value of the objects was reversed for only one trial, and was then shifted back to the original relationship. After many problems, the monkeys learned to ignore the single reversal and treated it as if the experimenter had made an error!

The problem was made more complicated, in another test, by offering the subjects a choice among three objects instead of two. There is a tray containing three food wells. Two are covered by one kind of object, and the third is covered by another kind. The animal must choose the odd object. Suppose the objects are building blocks and funnels. In half the trials, there are two blocks and a funnel, and the correct object is the funnel. Then a switch is made to two funnels and one block. Now the correct object is the block. The animal must learn a subtle distinction here it is not the shape of the object that is important, but its relation to the other two. The meaning of a specific object may change from trial to trial. This problem is something like the one a child faces in trying to learn to use the words "I," "you," and "he" properly. The meaning of the words changes according to the speaker. When the child is speaking, "I" refers to himself, "you" to the person addressed, and "he" to some third person. When the child is addressed, the child is no longer "I" but "you." And when others speak of him, the terms shift again

Monkeys and children were trained on a series of these oddity problems, 24 trials being allowed for the solution of each problem. At first they floundered, but they improved from problem to problem until they learned to respond to each new problem with perfect or nearly perfect scores. And on this complex type of problem the monkeys did better than most of the children!

ONE of the most striking findings from these tests was that once the monkeys have formed these learning sets, they retain them for long periods and can use them appropriately as the occasion demands. After a lapse of a year or more, a monkey regains top efficiency, in a few minutes or hours of practice, on a problem that it may have taken many weeks to master originally.

All our studies indicate that the ability to solve problems without fumbling is not inborn but is acquired gradually. So we must re-examine the evidence offered in support of the theory that animals possess some innate insight that has nothing to do with learning.

The cornerstone of this theory is the work of the famous Gestalt psychologist Wolfgang Kohler on the behavior of chimpanzees. In a series of brilliant studies he clearly showed that these apes can use sticks to help them obtain bananas beyond their reach. They employed the sticks to knock the bananas down, to rake them in, to climb and to vault. The animals sometimes assembled short sticks to make a pole long enough to reach the food, and even used sticks in combination with stacked boxes to knock down high-dangling bait. That the chimpanzees frequently solved these problems suddenly, as if by a flash of insight, impressed Kohler as evidence of an ability to reason independently of learning. He even suggested that this ability might differentiate apes and men from other animals.

Unfortunately, since Kohler's animals had been captured in the jungle, he had no record of their previous learning. Recent studies on chimpanzees born in captivity at the Yerkes Laboratory of Primate Biology at Orange Park, Fla., throw doubt on the validity of Köhler's interpretations. Herbert Birch of the Yerkes Laboratory reported that when he gave sticks to four-year-old chimps in their cages, they showed little sign at first of ability to use them as tools. Gradually, in the course of three days, they learned to use the sticks to touch objects beyond their reach. Later the animals solved very simple stick problems fairly well, but they had difficulty with more complex problems.

Extending Birch's investigations, the late Paul Schiller presented a series of stick tasks to a group of chimpanzees from two to over eight years of age. The younger the animal, the more slowly it mastered the problems. Some young subjects took hundreds of trials to perform efficiently on even the simplest problems, while old, experienced animals solved them with little practice. None of the apes solved the tasks initially with sudden insight.

Even at the human level there is no evidence that children possess any innate endowment that enables them to solve tool problems with insight. Augusta Alpert of Columbia University tried some of Kohler's simple chimpanzee tests on bright nursery-school children. The younger children typically went through a trial-and-error process before solving the problems Some of them failed to solve the easiest problem in the series in five experimental sessions..

Eunice Mathieson presented more difficult Köhler-type tasks to a group of University of Minnesota nursery-school children. The results were even more overwhelmingly against the notion that tool problems are solved by flashes of natural insight. The children rarely solved a problem without making many mistakes.

This research, then, supports our findings. In all clear-cut tests—that is, whenever the animals' entire learning history is known—monkeys, apes and children at first solve problems by trial and error. Only gradually does such behavior give way to immediate solutions.

WE began by pointing out that psychologists have sought to find in the higher mental processes some organizing mechanism or principle that would explain learning and thinking We can now suggest such a mechanism the learning set. Suppose we picture mental activity as a continuous structure built up, step by step, by the solution of increasingly difficult problems, from the simplest problem in learning to the most complex one in thinking. At each level the individual tries out various responses to solve each given task. At the lowest level he selects from unlearned responses or previously learned habits. As his experience increases, habits that do not help in the solution drop out and useful habits become established. After solving many problems of a certain kind, he develops organized patterns of responses that meet the demands of this type of situation. These patterns, or learning sets, can also be applied to the solution of still more complex problems. Eventually the individual may organize simple learning sets into more complex patterns of learning sets, which in turn are available for transfer as units to new situations

Thus the individual learns to cope with more and more difficult problems At the highest stage in this progression, the intelligent human adult selects from innumerable, previously acquired learning sets the raw material for thinking. His many years of education in school and outside have been devoted to building up these complex learning sets, and he comes to manipulate them with such ease that he and his observers may easily lose sight of their origin and development.

The fundamental role that language plays in the thinking process may be deduced easily from our experiments. They suggest that words are stimuli or signs that call forth the particular learning sets most appropriate for solving a given problem. If you listen to yourself "talk" while you are thinking, you will find that this is exactly what is happening. You review the different ways of solving a problem, and decide which is the best. When you ask a friend for advice, you are asking him to give you a word stimulus which will tell you the appropriate learning set or sets for the solution of your problem.

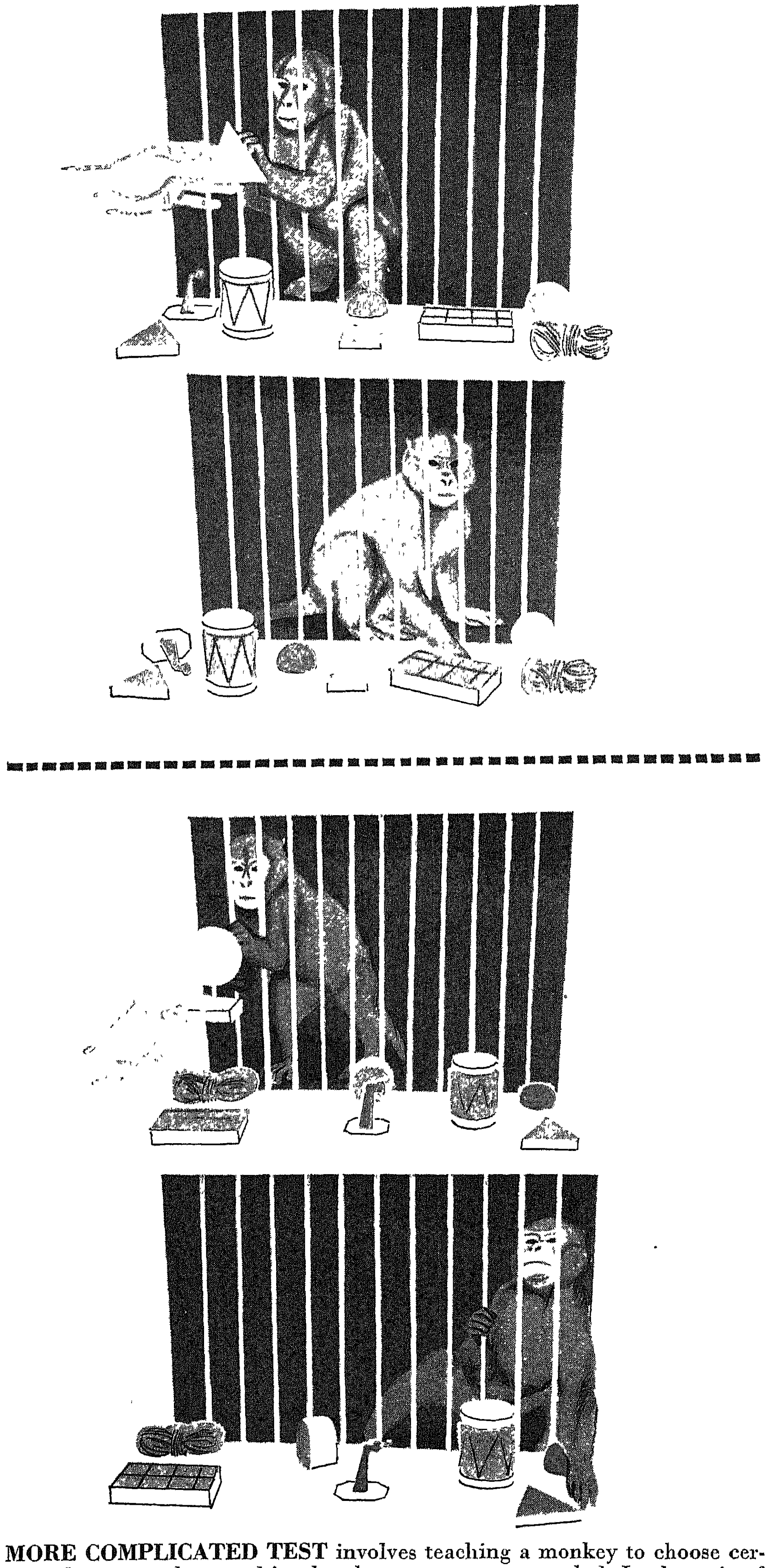
This principle is particularly well illustrated by some of our monkey experiments. Though monkeys do not talk, they can learn to identify symbols with appropriate learning sets. We have trained our monkeys to respond to signs in the form of differently colored trays

on which the test objects appear In one test the monkeys were presented with three different objects—a red U-shaped block, a green U-shaped block and a red cross-shaped block. Thus two of the objects were alike in form and two alike in color. When the objects were shown on an orange tray, the monkeys had to choose the green block, that is, the object that was odd in color. When they were shown on a cream-colored tray, the animals had to choose the cross-shaped block, that is, the object odd in form. After the monkeys had formed these two learning sets, the color cue of the tray enabled them to make the proper choice, trial after trial, without error. In a sense, the animals responded to a simple sign language. The difficulty of this test may be judged by the fact that the German neurologist Kurt Goldstein, using similar tests for human beings, found that people with organic brain disorders could not solve such tasks efficiently.

At the Wisconsin laboratories, Benjamin Winsten devised an even more difficult test for the monkeys This problem tested the animals' ability to recognize similarities and differences, a kind of task frequently used on children's intelligence tests. Nine objects were placed on a tray and the monkey was handed one of them as a sample The animal's problem was to pick out all identical objects, leaving all the rest on the tray. In the most complicated form of this test the monkey was given a sample which was not identical with the objects to be selected but was only a symbol for them. The animal was handed an unpainted triangle as a sign to pick out all red objects, and an unpainted circle as a sign to select all blue objects. One monkey learned to respond almost perfectly. Given a triangle, he would pick every object with any red on it; given a circle, he selected only the objects with blue on them.

All these data indicate that animals, human and subhuman, must learn to think. Thinking does not develop spontaneously as an expression of innate abilities, it is the end result of a long learning process. Years ago the British biologist, Thomas Henry Huxley, suggested that "the brain secretes thought as the liver secretes bile." Nothing could be further from the truth. The brain is essential to thought, but the untutored brain is not enough, no matter how good a brain it may be. An untrained brain is sufficient for trial-and-error, fumble-through behavior, but only training enables an individual to think in terms of ideas and concepts.

Harry F. Harlow is professor of psychology at the University of Wisconsin. Margaret Kuenne Harlow, his wife, is assistant professor of psychology at the same institution.



MORE COMPLICATED TEST involves teaching a monkey to choose certain objects not by matching but by response to a symbol. In the pair of drawings at the top of this page the monkey is shown a triangular object and pushes forward all the red objects. In drawings at bottom the monkey, shown a round object, pushes forward blue objects, here indicated by gray tone.

GALILEO

The massive achievements of the Italian physicist, astronomer and mathematician mark the transition from the Middle Ages to the era of modern science

by I. Bernard Cohen

PROBABLY no single name in the annals of science is as well known as that of Galileo. Yet so conflicting are the opinions in the literature on his work that it is difficult for the average scientist to find out exactly what Galileo did. Some writers tell us that Galileo was an empiricist who inaugurated the "scientific method" of learning "general truths of nature," and they illustrate by citing his supposed discovery of the laws of falling bodies by patient observation of what happened when balls of unequal weight were dropped from the Leaning Tower of Pisa. Others say that, on the contrary, Galileo never learned anything by making experiments; he used them only to check results which he had already obtained by mathematical reasoning and deductions from *a priori* assumptions. Many writers hail Galileo as the father of modern science. Others argue that almost everything Galileo did in science had been begun in the late Middle Ages. Many commentators agree with Sir David Brewster, who wrote of Galileo as one of the "martyrs of science." Others accept A. N. Whitehead's remark that Galileo's punishment by the Roman Inquisition was only "an honorable detention and a mild reproof before dying peaceably in bed."

What shall a scientist do when he is faced with making a choice between diametrically opposed points of view held by such respected writers? The example of Galileo provides one of the best possible arguments for the need of a continuing and increasing scholarship in the history of science. For if we are to understand the true significance of what Galileo did in physics and astronomy, obviously we must first have a clear picture of the scope and nature of the science that existed at the time he did his work, and next a knowledge of the history of physical science since his time, so that we may evaluate those elements which have proved most fruitful for the development of science.

The difficulty in interpreting Galileo stems in large part from the nature of his own thought and writings. He lived in that fertile period which marks the end of the Middle Ages and Renaissance and the beginning of the era of modern science. Thus he was a transitional figure with one foot in the past and the other striding into the future. Considering this state of affairs, one would need an unwarranted vanity to attempt to patch up all the contradictions in the various interpretations that have been made during the last hundred years. Yet certain clearly marked aspects of Galileo's achievement do emerge.

Galileo was a physicist, an astronomer and a mathematician. The first significant contribution to astronomy by Galileo occurred in 1604 while he was a professor in Padua, a post he had received in 1592 at the age of 28. The occasion was a new star seen in the heavens, a nova, which had aroused great interest among scientists, students and laymen everywhere. In a public lecture Galileo demonstrated, on the basis of careful observation, that the new star was truly a star It could not be a mere meteor in the Earth's atmosphere, for it had no parallax and must be very distant, among the fixed stars well beyond our solar system. Galileo predicted that the nova would be visible for a short while and then would vanish into obscurity.

The boldness of this assertion is difficult to realize today. The outlook on the external world then was largely Aristotelian; it was generally believed that the heavens were perfect and unchangeable and subject neither to growth nor to decay. Only the Earth, the center of the universe, could change. The laws of physics on Earth were essentially different from those in the celestial beyond.

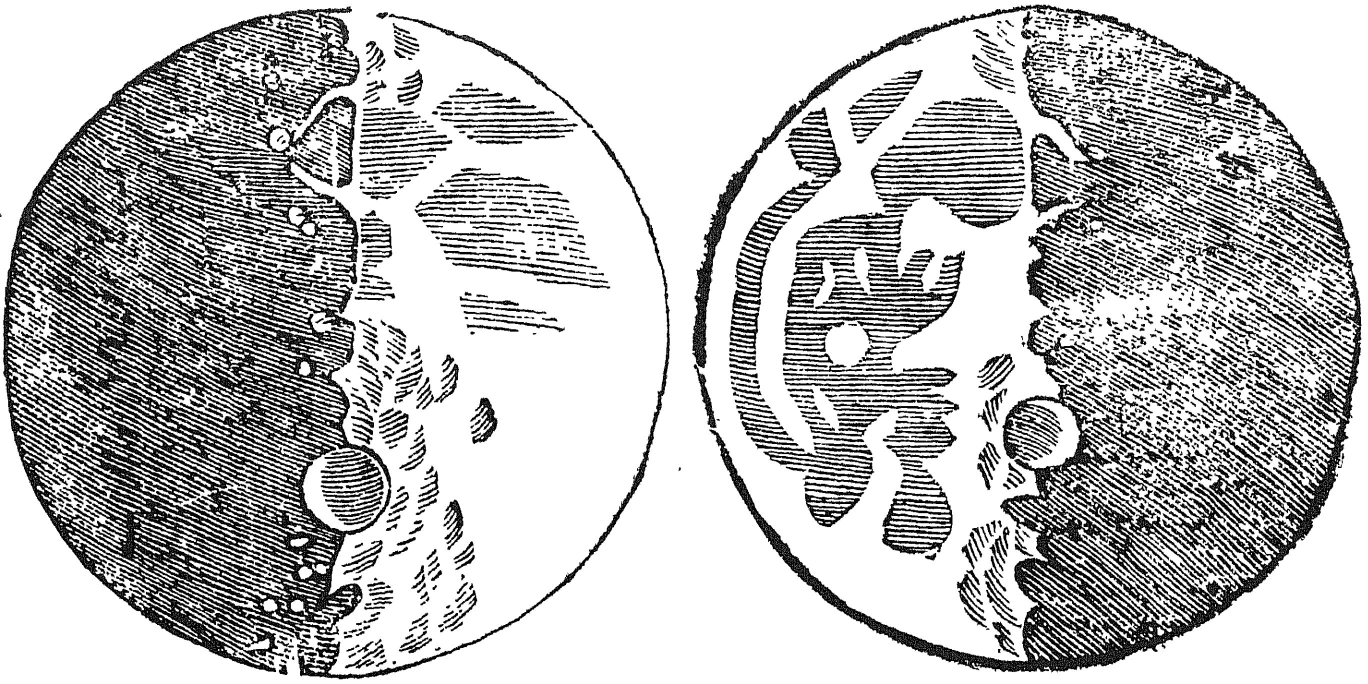
Galileo's assertion that the perfect and unchangeable heavens might witness growth and decay brought him into immediate conflict with the Aristotelians. The latter, as one of Galileo's biographers, J. J. Fahie, puts it, were probably as much "annoyed at the appearance of the star" as at Galileo's "calling attention to it so publicly and forcibly." In any event, Galileo was a better target than the star. Galileo was never one to shrink from controversy, and he seized the opportunity to repudiate the old physics of Aristotle, which he held to be inadequate, and with it the Ptolemaic, or geocentric, system of the universe.

GALILEO had already been a confirmed Copernican for some time, although he had not dared to publish his arguments, "fearing," as he said in a letter to Johann Kepler, "the fate of our master, Copernicus." Soon after his studies of the new star, however, Galileo was provided with an extraordinary opportunity to vindicate the Copernican idea. This occasion was the most important event in Galileo's career as an astronomer. He wrote.

"About ten months ago a rumor came to our ears that an optical instrument had been elaborated by a Dutchman, by the aid of which visible objects, even though far distant from the eye of the observer, were distinctly seen as if near at hand, and some stories of this marvelous effect were bandied about, to which some gave credence and which others denied. The same was confirmed to me a few days after by a letter sent from Paris by the noble Frenchman Jacob Badovere, which at length was the reason that I applied myself entirely to seeking out the theory and discovering the means by which I might arrive at the invention of a similar instrument, an end which I attained a little later, from considerations of the theory of refraction; and I first prepared a tube of lead, in the ends of which I fitted two glass lenses, both plane on one side, one being spherically convex, the other concave, on the other side."

Thus in his great book *The Sidereal Messenger*, which he published in Venice

GALILEO GALILEI was born in 1564 and died in 1642. This portrait of him appears in his book *Siderius Nuncius* (*The Sidereal Messenger*), printed in 1610. The initial letter of this article is also reproduced from *Siderius Nuncius.* The type used for the title of the article is from a 1632 edition of Galileo's dialogues.



FEATURES OF THE MOON were first clearly seen by Galileo through his telescope. He wrote: "... the moon is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere...." These two woodcuts are from a later edition of *Siderius Nuncius* published in 1655.

in 1610, did Galileo describe his introduction to the telescope. There are several independent claimants to the invention, but there is no doubt that Galileo was the first to turn the telescope to observation of the heavenly bodies. It was an experience unique in the history of man. For millennia the heavens had been viewed only by the naked eye, and no one knew what glories might exist beyond the range of man's unaided vision. Wherever Galileo pointed his telescope he found extraordinary and astonishing new facts.

Galileo first examined the Moon. His conclusion was "that the surface of the Moon is not perfectly smooth, free from inequalities and exactly spherical, as a large school of philosophers considers with regard to the Moon and the other heavenly bodies, but ... on the contrary, it is full of inequalities, uneven, full of hollows and protuberances, just like the surface of the Earth itself, which is varied everywhere by lofty mountains and deep valleys" Galileo even determined the height of the mountains on the Moon, and his results agree with modern determinations in order of magnitude. He believed at first that the dark and light areas on the Moon's surface represented land and water, but we must remember that even today beginning students of astronomy, on first looking at the Moon or at a photograph of it, have the same impression.

NEXT Galileo turned to the stars, and at once discovered a difference between the fixed stars and the planets, or wanderers. "The planets present their discs perfectly round, just as if described with a pair of compasses, and appear as so many little moons, completely illuminated and of a globular shape; but the fixed stars do not look to the naked eye [as if they were] bounded by a circular circumference, but rather like blazes of light shooting out beams on all sides and very sparkling, and with the telescope they appear of the same shape as when they were viewed by simply looking at them. . . ." Galileo also noted that the telescope brought within the range of vision "a host of other stars, which escape the unassisted sight, so numerous as to be almost beyond belief. . . ."

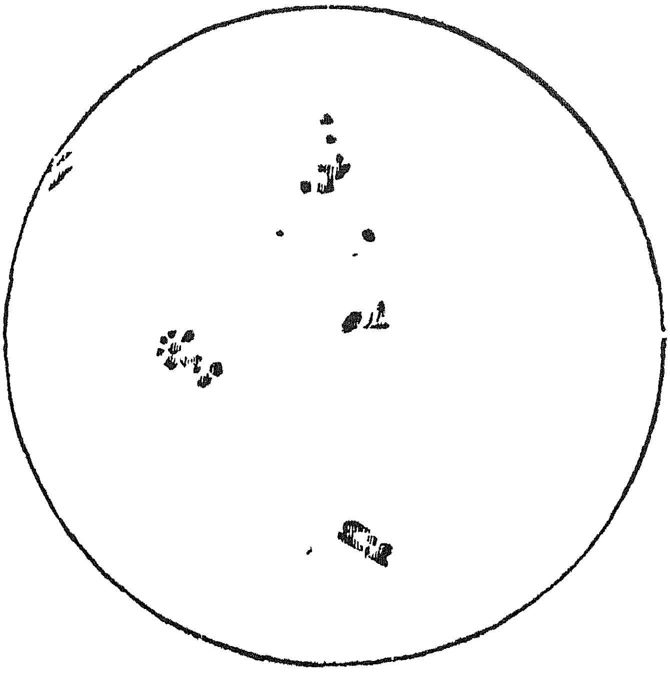
The next subject of his observation was the Milky Way, which, to his astonishment, he found to be "nothing else but a mass of innumerable stars planted together in clusters." Furthermore, all of the "nebulosities," whose nature had long been a topic of dispute, also proved to be masses of stars.

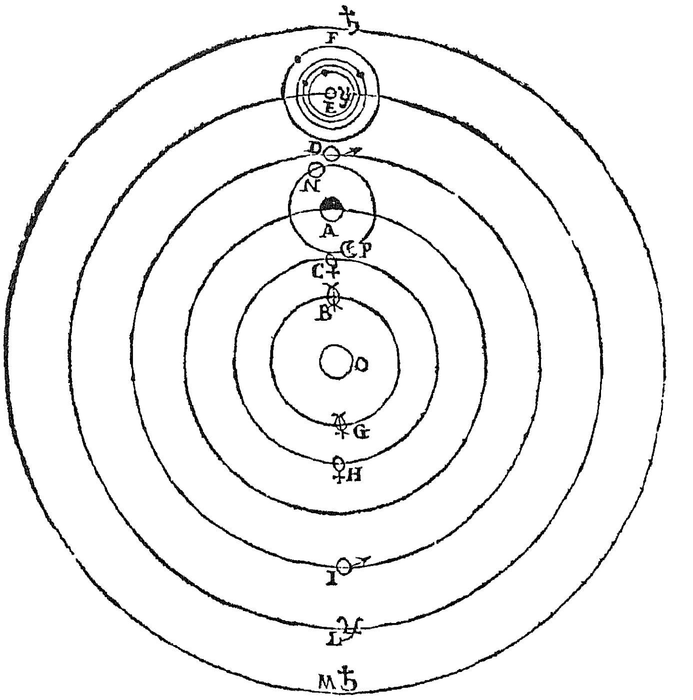
Galileo reserved for last in his account "the matter, which seems to me to deserve to be considered the most important in this work, namely, that I should disclose and publish to the world the occasion of discovering and observing four PLANETS, never seen from the very beginning of the world up to our own times. . . ."

He had been examining the planet Jupiter on the seventh day of January in 1610 when he noticed "that three little stars, small but very bright, were near the planet; and although I believed them to belong to the number of the fixed stars, yet they made me somewhat wonder, because they seemed to be arranged exactly in a straight line, parallel to the ecliptic, and to be brighter than the rest of the stars, equal to them in magnitude. . . . On the east side [of Jupiter] there were two stars, and a single one towards the west. . . . But when on January 8th, led by some fatality, I turned again to look at the same part of the heavens, I found a very different state of things, for there were three little stars all west of Jupiter, and nearer together than on the previous night, and they were separated from one another by equal intervals, as the accompanying illustration shows."

Night after night Galileo continued to observe this group of "stars," and finally he "decided unhesitatingly, that there are three stars in the heavens moving about Jupiter, as Venus and Mercury round the Sun; which at length was established as clear as daylight by numerous other subsequent observations. These observations also established that there are not only three, but four erratic sidereal bodies performing their revolutions round Jupiter. . . ."

Galileo wrote that the discovery of Jupiter's four moons, which he called "planets," provided "a notable and splendid argument to remove the scruples of those who can tolerate the revolution of the planets round the Sun in the Copernican system, yet are so disturbed by the motion of one Moon about the Earth ... for now we have not one planet only revolving about another ... but four satellites circling about Jupiter, like the Moon about the Earth, while the whole system travels over a mighty orbit about the Sun in the space of twelve years." Galileo discovered another important fact: that the planet Venus has phases like those of the Moon; it waxes and wanes from a full





SPOTS OF THE SUN were also observed by Galileo. Before his time the sun had been considered a "perfect" body. Woodcut is from *Macchie Solaris,* printed in 1613.

SYSTEM OF COPERNICUS was defended in Galileo's dialogues, from a 1632 edition of which this woodcut is taken. Illustration shows six planets and five moons.

orb to a thin crescent. "From the observation of these wonderful phenomena," wrote Galileo, "we are supplied with a determination most conclusive, and appealing to the evidence of our senses, of two very important problems, which up to this day were discussed by the greatest intellects with different conclusions. One is that the planets are bodies not self-luminous (if we may entertain the same views about Mercury as we do about Venus). . . . The second [is] that we are absolutely compelled to say that Venus (and Mercury also) revolves round the Sun, as do also all the rest of the planets. A truth believed indeed by the Pythagorean school, by Copernicus, and by Kepler, but never proved by the evidence of our senses, as it is now proved in the case of Venus and Mercury."

The discovery of the phases of Venus directly challenged the accepted Ptolemaic system. According to this system, Venus moved in an epicycle, a circular orbit whose center always lay between the Earth and the Sun. If this were true, then Venus, shining, as Galileo showed, by reflected light from the Sun, might be seen in some of its crescent phases, but we would never expect to see Venus as a half circle, a full circle, or any phases between. Yet Galileo observed all these phases.

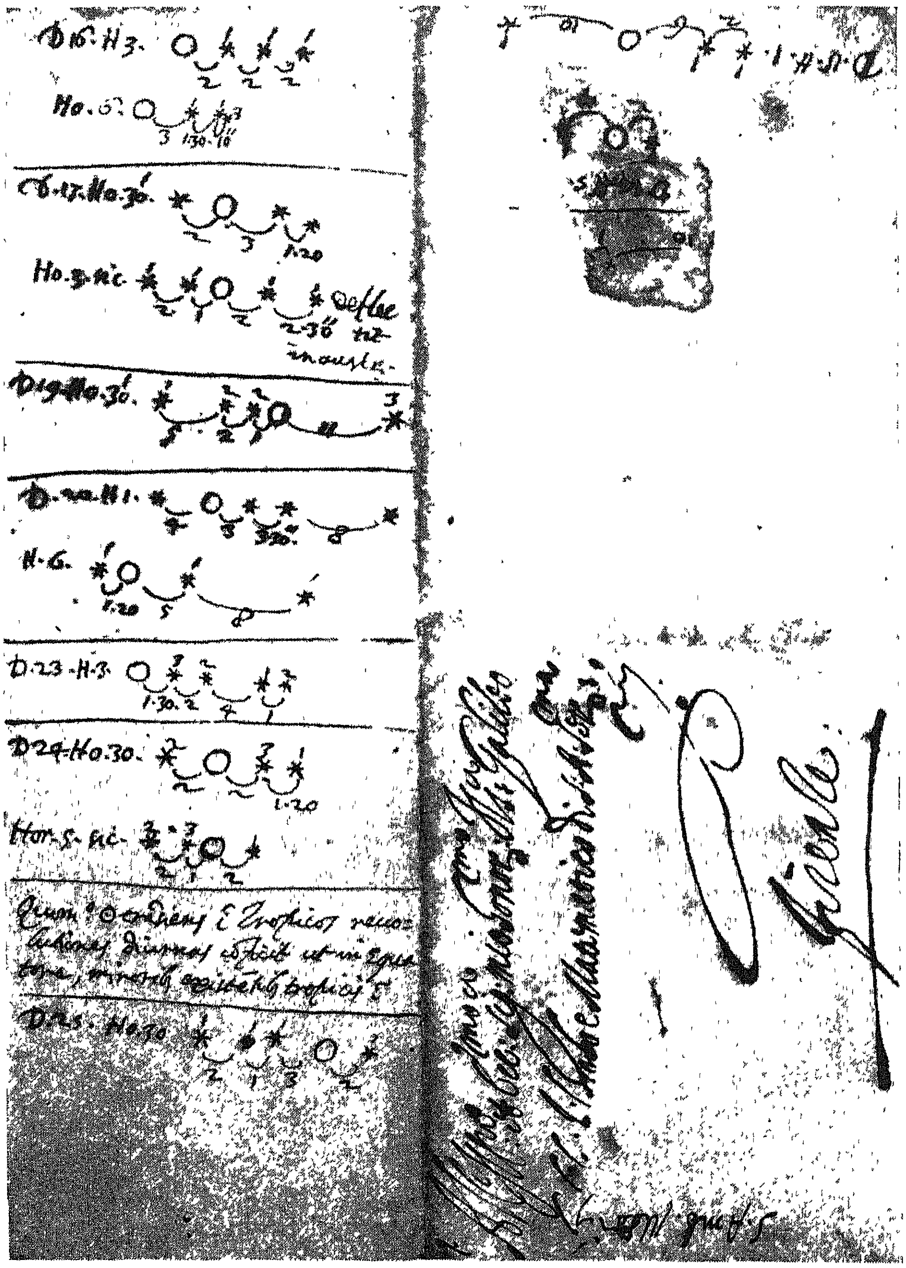
GALILEO'S discoveries made the Copernican system "philosophically reasonable" by showing that the Earth was like the other planets and the Moon. By observing the dark half of the quarter moon, faintly illuminated by earthshine, he demonstrated that the Earth shone just like the planets. If observed through a telescope located on the Moon or on Venus, the Earth would exhibit phases like theirs. As Galileo put it, "The Earth, with fair and grateful exchange, pays back to the Moon an illumination like that which it receives from the Moon nearly the whole time during the darkest gloom of night."

The Sun, by contrast, was self-luminous and thus set apart from the Earth, the Moon and the planets If any single body was especially constituted to be at the center of the universe, surely it was the Sun and not the Earth! And as a model for this picture of the solar system, with the Sun at the center and its attendant planets circling it, there was Jupiter with its four satellites revolving about it in the same way.

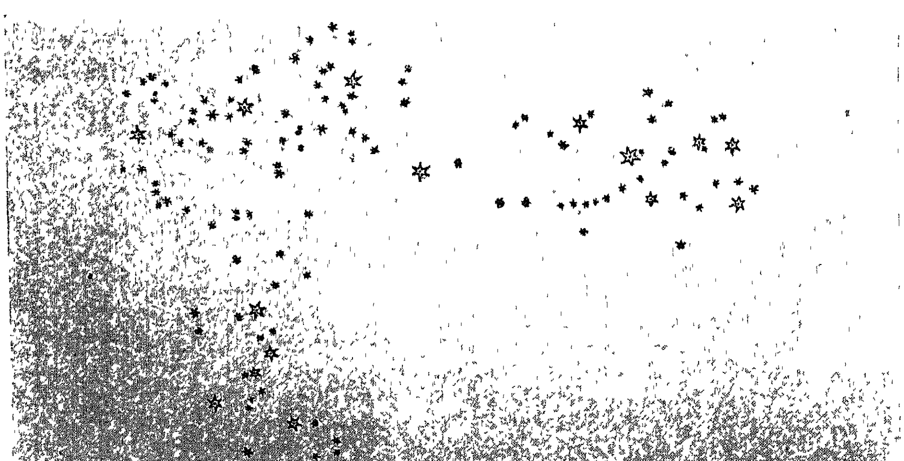
Galileo's lifework shows a unity of purpose and achievement that is rare among men of science. His work in mechanics fitted in with his work in astronomy like an adjacent piece of a jigsaw puzzle. It is clear from his writings that Galileo was at heart a gadgeteer with true mechanical feeling and inventive genius. One of his earliest discoveries was that a pendulum always makes a complete swing in the same period of time, no matter what the length of the swing. He speedily applied this discovery to the invention of the "pulsilogium," a device for mechanically recording and comparing pulse rates. Aside from his natural bent for mechanics, however, Galileo was strongly attracted to this subject because, in part at least, he thought of it as a cosmological science, the link between earthly and celestial phenomena. If he could find the laws of motion on Earth, he could apply them to the motions of the planets and the stars. It was thus his ambition to show that if one adopted the Copernican system, the planets followed their patterns in the heavens by regular and simple laws, and not, as in the older theory, because each was guided by a "special intelligence."

In seeking a universal science of mechanics that would apply equally to the heavens and the Earth, Galileo was, of course, flying directly in the face of the contemporary point of view. The Aristotelian conception made a sharp distinction between motion on the Earth and Moon and motion in the translunar, "celestial" universe. In the sublunar world, "natural motion" occurred in a straight line. An apple fell downward from the tree because it was "heavy" and its natural place was "down"; to make it go in any other direction contrary to its nature required a "violent motion." In the translunar world, by contrast, the natural motion was circular, as befitted the perfect material out of which the celestial bodies were made.

By showing the similarity between the Earth, Moon and planets, which indicated that they must obey the same laws, Galileo brought terrestrial and celestial phenomena within one universal physics. The revolution in physical thinking effected by Galileo may be thought of as concentrating men's attention on change and on motion. He proved that even the Sun, that most "perfect" of all heavenly bodies, was subject to change, for when viewed by Galileo's telescope it showed changing spots! Anyhow, as Galileo put the matter, it was no "great honor" for bodies to be immutable and



MOONS OF JUPITER were drawn by Galileo's own hand on a letter addressed to him. The drawings show positions of the moons at different times.



THE PLEIADES were delineated in a 1610 edition of *Siderius Nuncius.* Galileo's telescope had made visible the smaller stars of the famed cluster.

unalterable, nor was the Earth "corrupt" because it changed.

"It is my opinion," he asserted, "that the earth is very noble, and admirable, by reason of so many and so different alterations, mutations, generations, etc., which are incessantly made therein, and if without being subject to any alteration, it had been all one vast heap of sand, or a masse of jasper, or that . . . it had continued an immense globe of christal, wherein nothing had ever grown, altered, or changed, I should have esteemed it a lump of no benefit to the world, full of idleneses, and in a word superfluous. . . What greater folly can there be imagined, than to call jems, silver and gold pretious; and earth and dirt vile? For do not these persons consider, that if there should be as great a scarcity of earth, as there is of jewels and pretious metals, there would be no prince, but would gladly give a heap of diamonds and rubies, and many wedges of gold, to purchase onely so much earth as should suffice to plant a Gessemine in a little pot, or to set therein a China Orange [tangerine], that he might see it sprout, grow up, and bring forth so goodly leaves, so odoriferous flowers, and so delicate fruit? It is therefore scarcity and plenty that makes things esteemed and contemned by the vulgar. . . ."

WE SHALL consider here only three aspects of Galileo's mechanics: the law of falling bodies, the principle of inertia, and the resolution and composition of independent motions. The law of falling bodies is the most celebrated of Galileo's discoveries. Modern scholarship has shown that Galileo's work on falling bodies was original not so much in his own statement of the law as in the particular use he made of it. Aristotle had said that the speed of a given falling body depended on the resistance of the medium in which it fell, *e.g.,* a stone obviously will fall faster in air than in water. He had also said that if two bodies were to fall in a resistant medium like air, their speed would depend on their weight. Even before Galileo, many writers had expressed their doubts concerning this dictum. In the sixth century, John Philoponos had demonstrated by an experiment that the contrary was true. Galileo approached the problem by using the principles of deductive reasoning and mathematics rather than by direct experiment.

He considered two possibilities in the case of a uniformly accelerated motion starting from rest: 1) that the speed was proportional to the distance fallen, 2) that it was proportional to the elapsed time. The first led to an apparent contradiction, so he accepted the second, the now familiar law that the velocity equals the acceleration times the time—$v=At$. Then, making use of the well-

known proof that a uniformly accelerated body moves through a distance s in any time t equal to the distance it would have fallen in the same time t with the average velocity, he derived the equivalent of the law. $s=\frac{1}{2}At^2$.

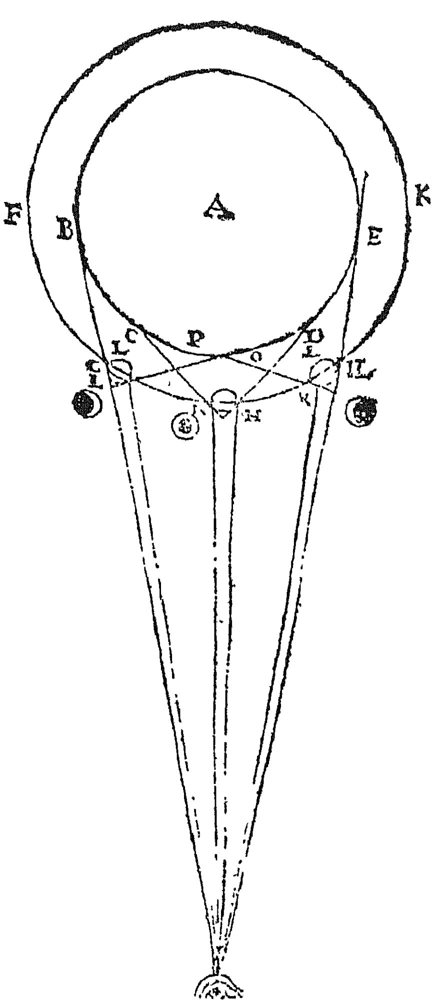
As a check, Galileo proposed an experiment on an inclined plane. This test was a means of "diluting gravity," so that one could study the relatively slow rolling motion by timing it with a water clock. The test depended on Galileo's important theorem of the composition of motions. A body moving down an inclined plane, in the Galilean scheme, has two components: a horizontal or forward motion, and a vertical or falling motion. Each is independent of the other. By making a rough check with an inclined plane, he demonstrated that the law $s=\frac{1}{2}At^2$ seemed to hold along the inclined plane. From this he inferred that it also held for freely falling bodies.

Here we have a typical example of Galileo's method in physics: Imagine the conditions of a given situation, make a mathematical formulation and derive the reasonable consequences, then make a rough check, if it seems necessary, to be sure that the result is correct. His experimental test involved a brass ball rolling in a groove. He measured the time for different distances, at varying angles of inclination of the grooved board. In "experiments near an hundred times repeated," Galileo found that the times agreed with the law, with no differences "worth mentioning." His conclusion that the differences were not "worth mentioning" only shows how firmly he had made up his mind beforehand, for the rough conditions of the experiment would never have yielded an exact law. Actually the discrepancies were so great that a contemporary worker, Père Mersenne, could not reproduce the results described by Galileo, and even doubted that he had ever made the experiment.

Once Galileo had satisfied himself that he knew the law of falling bodies, he wished to apply it. He knew full well that the law would work precisely only in an ideal situation—one in which there was no resisting medium—but he nevertheless decided to apply it to falling bodies in air, since he observed that the effect of the air resistance was small for a heavy body such as a cannon ball.

Keeping in mind that motion in air departs slightly from the ideal case, Galileo next applied his principles to the problem of determining the trajectory of a projectile. According to the Galilean analysis, a projectile has two independent components of motion, horizontal and vertical, like the ball on the inclined plane. If fired horizontally from a gun, it moves forward the same distance in every second if we disregard the small factor of air resistance. As it emerges from the barrel it also begins to fall toward the earth. During the first second it will fall 16 feet, during the second second, 48 feet; during the third, 80 feet, and so on. Hence the path of the shell will be a parabola. Here was a brand new discovery that was of the utmost practical importance in the new science of artillery-ranging.

Implicit in Galileo's analysis was another brand new idea: the principle of inertia. While he did not state it explicitly, in his assumptions about the movement of the projectile he made use



PHASES OF VENUS, which Galileo was the first to observe, were one of the several arguments he used in his opposition to the Ptolemaic system.

of the theorem that a body will continue in uniform motion in a straight line unless acted on by an outside force. Galileo introduced the revolutionary concept, contrary to all older physics, that uniform motion in a straight line is physically equivalent to a state of rest, thereby transforming the science of mechanics from a static to a kinematic basis.

These new principles gave the first complete explanation of the mechanics of the Copernican universe. Now one could explain why a stone dropped from a tower would fall at the base of the tower even though the Earth had moved while the ball fell. One could also understand for the first time why a stone dropped from the masthead of a moving ship would fall at the foot of the mast in spite of the movement of the ship. Galileo pointed out that the stone partakes of the ship's forward motion before it is dropped, and this forward motion continues unchanged while the stone falls because the forward and the downward motions are independent. Consequently an observer on such a boat could not tell from this experiment whether the boat was at rest or in uniform motion. In other words, an observer cannot distinguish between a state of rest and of uniform motion save with regard to an observable external system of reference. This is the principle of Galilean relativity. He observed: "In respect to the Earth, to the Tower, and to our selves, which all as one piece move with the diurnal motion together with the stone, the diurnal motion is as if it had never been."

At this point the reader may ask: What about the story of the famous experiment in which Galileo dropped two balls of unequal size and weight from the Leaning Tower of Pisa? At some time and place, he did drop two unequal weights and found that they did not hit the ground with the great difference that Aristotle had predicted. But it appears from modern scholarship that he never did so, at least publicly, from the Pisan tower.

Galileo worked out his physics by thought, by correct reasoning and mathematics, not by induction from experiments. During his days at Pisa, before he went to Padua, he wrote: "But, as ever, we employ reason more than examples (for we seek the causes of effects, and they are not revealed by experiment)." Galileo liked to use what we may call "thought experiments," imagining the consequences rather than observing them directly. Indeed, when he described the motion of a ball dropped from the mast of a moving ship, in his *Dialogue on the Two Great Systems of the World*, he then had the Aristotelian, Simplicio, ask whether he had made an experiment, to which Galileo replied: "No, and I do not need it, as without any experience I can affirm that it is so, because it cannot be otherwise."

To confute the supposed results of Aristotelian logic Galileo made a frontal attack on Aristotelians. For example, he pointed out that "it may be possible, that an artist may be excellent in making organs, but unlearned in playing on them, thus he might be a great logician, but unexpert in making use of logick; like as we have many that theorically understand the whole art of poetry, and yet are unfortunate in composing but mere four verses; others enjoy all the precepts of Cinci, and yet know not how to paint a stoole. The playing on the organs is not taught by them who know

how to make organs, but by him that knows how to play on them, poetry is learnt by continual reading of poets: limning is learnt by continual painting and designing. demonstration from the reading of books full of demonstrations, which are the mathematical onely, and not the logical "

As for Aristotle's appeal to the experience of the senses, Galileo asks "And doth he not likewise affirm, that we ought to prefer that which sense demonstrates, before all arguments, though in appearance never so well grounded? and saith he not this without the least doubt or hesitation?" To which Simplicio, the Aristotelian, replies, "He doth so." Then, says Galileo, ". . . you shall argue more Aristotelically, saying, the heavens are alterable, for that so my sense telleth me, than if you should say, the heavens are unalterable, for that logick so perswaded Aristotle. Furthermore, we may discourse of coelestial matters much better than Aristotle, because, he confessing the knowledg thereof to be difficult to him, by reason of their remoteness from the senses, he thereby acknowledgeth, that one to whom the senses can better represent the same, may philosophate upon them with more certainty. Now we by help of the telescope, are brought thirty or forty times nearer to the heavens, than ever Aristotle came; so that we may discover in them an hundred things, which he could not see, and amongst the rest, these spots in the Sun, which were to him absolutely invisible; therefore we may discourse of the heavens and Sun, with more certainty than Aristotle."

Galileo's writings abound with references to the facts of experience, of direct observation. In this sense, Galileo built his science on a somewhat empirical basis. But he was in no sense such an empiricist as the 19th-century writers attempted to make him out. He was not a careful experimenter, though he was a keen observer, and it is only the fallacy of writing history backwards that has made us visualize him as the patient investigator who only reluctantly drew conclusions after long test. The latter picture describes a much later kind of scientific man, of whom the prototype may well have been Robert Boyle.

Galileo's greatest general contribution was the idea that mathematics was the language of motion, and that change was to be described mathematically, in a way that would express both its complete generality and necessity, as well as its universality and applicability to the real world of experience. While Galileo ridiculed the numerology aspect of Platonism, he declared in the opening pages of the *Dialogue:* "I know perfectly well that the Pythagoreans had the highest esteem for the science of number and that Plato himself admired the human intellect and believed that it participates in divinity solely because it is able to understand the nature of numbers. And I myself am well inclined to make the same judgment." That nature herself "loves the integers" was shown in Galileo's discovery that a falling body moves so that its speeds after successive seconds are in the ratio of whole numbers 1, 2, 3. . . . The distances fallen in successive seconds are in the ratio of the odd numbers 1, 3, 5. . . . The most important influence on Galileo's thinking undoubtedly was Archimedes, but whereas the latter had constructed a geometry of rest, Galileo built a geometry of motion

THE net result of Galileo's lifework was to adduce new evidence for the Copernican theory of the solar system, and to provide the mechanical rationale of its operation. One evidence of the success of this activity was the hostility his work aroused. In the evening of his life he was brought into conflict with the Roman Inquisition. Galileo took the point of view, as expressed in his famous letter to the Grand Duchess Cristina, that the Holy Scriptures did not have the teaching of science as their ultimate aim. He argued that the language of the Bible was not to be taken literally. Thus when the Sun was described as moving around the Earth, this did not imply the truth of the geocentric system, but was merely an expression in everyday language. (In the same way we still speak of the Sun rising and setting.) From this point of view, Galileo held that one could accept the Copernican system while remaining a good Catholic and without in any way impugning the Scriptures.

Had Galileo remained at Padua under the rule of Venice, which held herself independent of papal jurisdiction, he would never have had to face the Inquisition. But with the fame attendant on his initial discoveries with the telescope, he chose to move to Florence. There is a vast and readily available literature on Galileo's trial and condemnation, which will not be discussed in this article confined to his scientific work It is true that Galileo was never put to torture during his stay in the prison of the Inquisition. But the knowledge that others had been tortured there, and that not too long before Giordano Bruno had been burned alive, surely had their effects upon him. He was a man of 69 in poor health. Three physicians attempting to avert the trial had testified in 1633: "All these symptoms are worthy of notice, as under the least aggravation they might become dangerous to his life." The poor man, formerly eager for combat with those who would deny the new truths, was now crushed by the action of the Holy Office of the Church to which he had ever been faithful. Upon repeated examination, he "confessed":

"I, Galileo Galilei, son of the late Vincenzio Galilei of Florence, aged seventy years, being brought personally to judgment, and kneeling before you, Most Eminent and Most Reverend Lords Cardinals, General Inquisitors of the Universal Christian Commonwealth against heretical depravity, having before my eyes the Holy Gospels which I touch with my own hands, swear that I have always believed, and, with the help of God, will in future believe, every article which the Holy Catholic and Apostolic Church of Rome holds, teaches, and preaches. But because I have been enjoined, by this Holy Office, altogether to abandon the false opinion which maintains that the Sun is the centre and immovable, and forbidden to hold, defend, or teach, the said false doctrine in any manner . . . I am willing to remove from the minds of your Eminences, and of every Catholic Christian, this vehement suspicion rightly entertained towards me, therefore, with a sincere heart and unfeigned faith, I abjure, curse, and detest the said errors and heresies, and generally every other error and sect contrary to the said Holy Church; and I swear that I will never more in future say, or assert anything, verbally or in writing, which may give rise to a similar suspicion of me; but that if I shall know any heretic, or any one suspected of heresy, I will denounce him to this Holy Office, or to the Inquisitor and Ordinary of the place in which I may be. I swear, moreover, and promise that I will fulfil and observe fully all the penances which have been or shall be laid on me by this Holy Office. But if it shall happen that I violate any of my said promises, oaths, and protestations (which God avert!), I subject myself to all the pains and punishments which have been decreed and promulgated by the sacred canons and other general and particular constitutions against delinquents of this description. So, may God help me, and His Holy Gospels, which I touch with my own hands, I, the above named Galileo Galilei, have abjured, sworn, promised, and bound myself as above; and, in witness thereof, with my own hand have subscribed this present writing of my abjuration, which I have recited word for word."

One can only wonder at the indomitable spirit that enabled Galileo—shamed, confined, ill, his major work placed on the Index of Prohibited Books—to complete his last major work, *The New Sciences*, the publication of which had to be arranged surreptitiously. And today we may also wonder whether the fight for freedom of belief has yet been truly won. For we can repeat Galileo's tragic declaration: "Philosophy wants to be free!"

I Bernard Cohen, assistant professor of the history of science and of general education at Harvard University, is managing editor of the journal Isis.

DIALOGO

DI

GALILEO GALILEI LINCEO

MATEMATICO SOPRAORDINARIO

DELLO STVDIO DI PISA.

E Filoſofo, e Matematico primario del

SERENISSIMO

GR. DVCA DI TOSCANA.

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THE DIALOGUES were Galileo's exposition of "the two great systems of the world." In it his three characters debated for four days. The book resulted in his trial and imprisonment. Its first edition was printed in 1632. Shown here is the frontispiece of a presentation copy dedicated by the author. The word "LINCEO" which follows Galileo's name stands for the Society of Lynxes, a group of people interested in science.

RADIOACTIVITY AND TIME

The regular decay of radioactive isotopes provides evidence of the age of Egyptian tombs, Pleistocene sediments, pre-Cambrian rocks and the earth itself

by P. M. Hurley

ABOUT 15 years ago Eric Temple Bell, professor of mathematics at the California Institute of Technology, wrote a science-fiction tale called "Before the Dawn." A piquant item in this fantasy was an electronic televisor that projected events not in space but in time. When focused on ancient rocks, it could reconstruct on a large screen a motion picture of the story that the rocks had to tell. The machine re-enacted with photographic accuracy geological upheavals that had occurred on the site eons ago, and battles between animals now long extinct.

If modern geology cannot match the realism of Bell's automatic rock-reader, it can reconstruct the history of the earth with some accuracy and detail, at least for the last 15 per cent of the earth's age, the period covered by the fossil record. And it now has a technique which seems even more unreal than Bell's machine—a natural clock that gives us the time of events in the dim geologic past. In other words, for the first time we can read in the rocks not only the sequence of happenings but their dates.

The discovery that made this possible was radioactivity. The slow decay of naturally radioactive elements in the earth's crust has ticked off the seconds since the earth was born with unalterable precision. The rates of disintegration of these elements are so unaffected by the temperatures and pressures of our planet that they may be considered fixed constants. Thus by measuring the amount of the elements' decay we can determine the age of the structure of which they are a part.

Effectively, the clocks began to tick when some molten part of the earth solidified into crystalline rock. When a single mineral crystal is formed, it contains certain predominating elements and a number of minor ones trapped in its structure as impurities. The radioactive element that serves us as a clock may be either a major or a minor constituent of this crystal. Let us say it is uranium. The element breaks down at a known rate, producing certain isotopes of lead as stable end-products. After a few tens of millions of years there is enough such lead in a sample of the rock to be measured chemically. By measuring the end product and the amount of radioactive uranium still left, one can determine the age of that particular rock. This in turn dates an event associated with the rock in the earth's history.

The method can be made clearer by considering a study of an actual mineral sample. The sample was a piece of samarskite, a velvety black, crystalline mineral, taken from the Spinelli Quarry in Glastonbury, Conn. This mineral contains uranium and thorium, both of which were utilized as clocks. In every 100 grams of the sample there were about seven grams of uranium, three grams of thorium and slightly more than three tenths of a gram of lead.

How much of this lead was the product of the breakdown of uranium and thorium, and how much of it was originally present in the samarskite when it crystallized? To find out, Alfred O. Nier of the University of Minnesota separated the tiny quantity of lead into its isotopes and measured them by means of a mass spectrometer. He measured the amounts of each of the four isotopes present, lead 204, 206, 207 and 208. Lead 206 is known to be a breakdown product, or daughter, of uranium 238; lead 207 is a daughter of uranium 235, and lead 208 is a daughter of thorium 232. But lead 204, fortunately, is not a daughter; it is a stable material, the amount of which has not been significantly increased by the breakdown of any possible progenitor in the past two or three billion years. Thus it serves as a measure of the amount of lead originally present in the sample.

In common lead the isotopes 204, 206, 207 and 208 appear in certain almost constant proportions. Assuming that the isotopes were present in these proportions in the samarskite before the breakdown products were added, the additions can be computed by measuring the change in the relative abundance of each isotope as compared with 204. The samarskite sample had .0004 of a gram of 204 in every 100 grams of the mineral. By comparing the amounts of the other isotopes in this sample with the amounts of the same isotopes associated with every .0004 of a gram of lead 204 in common lead, the amounts of added or radiogenic lead were determined.

Consider first thorium and its daughter, lead 208. In the samarskite sample there was .0518 of a gram of 208 for each .0004 of a gram of 204. In common lead the proportion is .0142 of a gram of 208 to .0004 of a gram of 204. Thus the difference, .0376 of a gram, was the amount of lead 208 produced by the disintegration of the original thorium. There were three grams of thorium left in the sample, from this the original amount of thorium could be computed. The half-life of thorium, *i.e.*, the time it would take for half of its atoms to disintegrate, is known to be 13.9 billion years. On the basis of these figures, the thorium clock showed that this rock was 266 million years old

NO SINGLE clock is entirely trustworthy, however, in this type of investigation. There is no assurance that we have an accurate estimate of the amount of the parent isotope originally present, or that some of the parent or daughter atoms have not escaped from the rock. For example, the crystals have been under constant bombardment for millions of years by alpha particles emitted by the radioactive elements. This barrage shatters some of the crystals, and some atoms may well leak out of the rock, particularly in the water-saturated zone near the earth's surface. In that case the amount of disintegration of the parent element cannot be determined accurately.

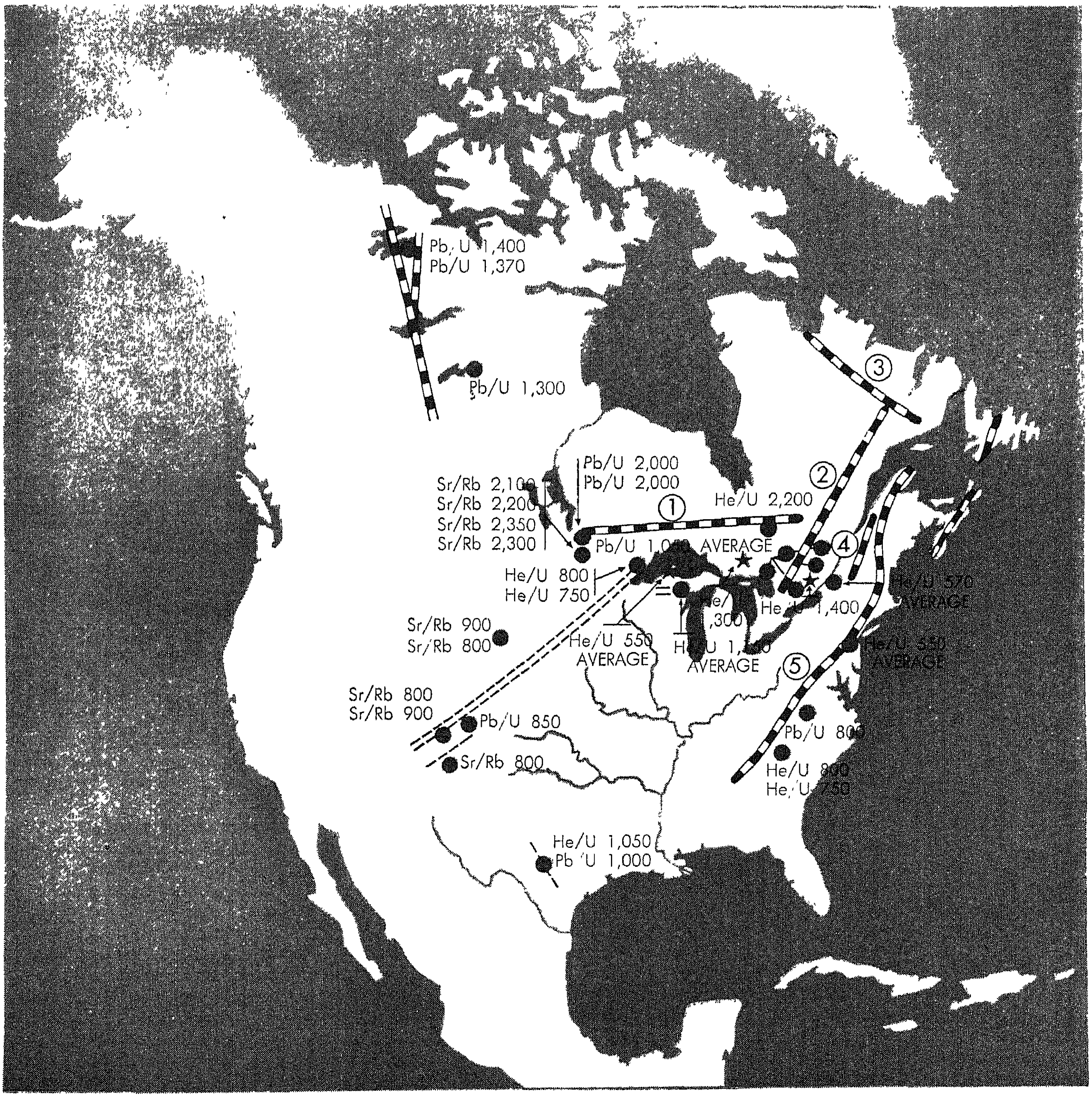
In the particular case of the samarskite sample, fortunately, there were no fewer than three other clocks available for checking. One was uranium 238, which has a half-life of 4.5 billion years and decays to lead 206 as its end product. The amount of its daughter lead was computed to be .236 of a gram per 100 grams, and so this clock gave 255 million years as the age of the rock. The second clock was uranium 235, which has a half-life of 707 million years and

yields lead 207. It gave 254 million years as the age of the rock. The third clock was based on the proportion of lead 207 to lead 206; because the half-lives of their parents, U-235 and U-238, differ, this ratio varies with time in a calculable manner. This clock timed the age of the rock as 256 million years. Thus the three uranium clocks showed remarkable agreement. The thorium measurement, apparently less accurate, was discarded, and the age of the sample was considered to be accurately fixed at about 255 million years.

Such close agreement is, of course, the exception rather than the rule. Moreover, it is not often that more than one clock is at hand to check the results. Because minerals with enough uranium or thorium in them to be usable for lead ratios are relatively rare, age determinations by this method frequently cannot be made where needed most. What geologists have sought is a measure that can be used on the small amount of radioactivity present in common rocks. Virtually all rocks have at least a little radioactivity; granites, for example, average about a tenth of an ounce of uranium per ton

There was great hope for a time that helium would provide this sensitive measure. Helium, whose atomic nuclei are alpha particles, is one of the products of the breakdown of uranium and thorium; *e.g.*, each atom of U-238, in decaying to stable lead, yields eight atoms of helium. Measurements of helium in rock samples at first seemed to give rock ages that agreed with those determined by lead measurements, but it was found later that this agreement was accidental and due to a compensating error.

There is almost always less helium in rocks that have crystallized out of a molten state than one would expect. In such rocks radioactive elements are concentrated in little pockets. Helium in the



AGES OF ROCKS in North America have been outlined by measurements based on radioactivity. Black and white strips indicate the roots of mountain belts, some of which are numbered in their order of development. Dotted lines denote possible mountain belts. Type of radioactive measurement is given by the ratio of one element to another, *e.g.*, a lead-uranium ratio is indicated as Pb/U. Rock ages are given in millions of years.

form of alpha particles is fired atom by atom into the crystal structures of the rock as bullets might be fired into a log. It is believed that the crystal structures eventually break down and allow some helium to escape from the rock. Rocks that have not crystallized out of a molten state do not bear their uranium and thorium in these highly concentrated pockets, so they are being investigated for their usefulness in the measurement of time by helium ratios. One mineral, magnetite, has been tested extensively, and the results derived from it are in general agreement with those derived from lead ratios.

The element rubidium is another useful clock. The radioactive isotope rubidium 87, with a half-life of about 58 billion years, decays to a stable isotope of strontium. Thus the age of minerals containing rubidium can be found by determining the ratio of Sr^{87} to Rb^{87}. Certain micas are rich in rubidium. In lithium mica it has been found that more than 98 per cent of the strontium present is the product of the decay of rubidium. Measurements of a number of minerals containing rubidium have yielded ages that agree reasonably well with those based on uranium and lead.

These various clocks have now given us an approximately accurate time scale for the geological periods since the beginning of the Cambrian Period of some 500 million years ago (*see chart on page 51*). In the map on page 49 are the calculated ages of some older rocks in North America. J. Tuzo Wilson of the University of Toronto has recently plotted belts of exposed pre-Cambrian rocks in the ancient formation known as the Canadian shield. From observations at places where these belts crossed one another, he determined their relative ages. The radioactive clocks agreed in general with Wilson's evidence. For instance, rocks in the belt that he judged to be the oldest showed the greatest age, two billion years, in the radioactivity measurements.

BUT WHAT about dating events in the Pleistocene—the brief last million years in which man has lived on the earth? The slow-paced clocks that we have been considering have no minute-hands; they are not refined enough to measure intervals as short as a fraction of a million years, the period in which anthropologists and glacial geologists are particularly interested. The events of this period have hitherto been dated by the ebb and flow of glaciers, by tree rings and by sedimentary layers—all of which have been unsatisfactorily restricted as clocks.

To measure lengths of time of a few thousand or hundred thousand years, we must use isotopes with half-lives of the same order of magnitude, instead of the millions or billions of years of uranium and thorium. It so happens that there are several convenient ones.

One useful clock is found in the sediments laid down on ocean floors. In their microorganic remains the sediments contain an unbroken record of changes in climatic conditions and surface-water temperatures over the whole Pleistocene Period. And mixed with the sediments, deposited in them out of sea water, is the radioactive isotope thorium 230, with a half-life of about 83,000 years. Thorium 230 is one of the intermediate products in the decay of uranium to lead. It has been found that the ratio of thorium 230 to uranium decreases in a regular manner with increasing depth of the sediments. If the amounts of thorium 230 and uranium are measured in closely spaced samples taken from the top of the sediments down, the rate of deposition of the thorium at any level, and the age of that level, can be calculated.

It is now possible to obtain samples of these sediments from any desired depth and location by means of a ship-borne rig that cuts a long core out of the ocean bottom. Cores 20 to 30 feet in length, representing the entire Pleistocene or even longer, have been brought up and studied. One interesting and important investigation in the Antarctic region has shown that glacial conditions have existed there for 1.1 million years, and that ice ages in the Southern Hemisphere apparently were contemporaneous with those in the Northern Hemisphere.

This clock will be particularly helpful to anthropologists, who are interested in the dates of glaciation and climatic change. The ethnologist, unearthing an early culture of man, needs a shorter time measurement. A clock suited to his needs may be forthcoming as a result of a most happy recent discovery by E. C. Anderson, W. F. Libby and others at the University of Chicago. This clock is the radioactive isotope carbon 14. Anderson and his co-workers found that carbon 14 is being created continuously in the atmosphere by cosmic radiation. Neutrons produced by cosmic rays convert part of the nitrogen 14 in the air into carbon 14. The amount of carbon 14 is not continuously increasing, but has reached a balance point where as much breaks down by radioactive decay as is formed. Thus the small amount of carbon 14 in the air remains constant, and it was probably the same hundreds of thousands of years ago as it is now. But any carbon 14 that is taken out of the air by some stable material on the earth (*e.g.*, a tree or animal) decays without replenishment if it is buried. It is possible, therefore, to date wood, sea shells or other materials containing carbon that are found with artifacts in a buried camp site or cave simply by measuring the proportion of the carbon 14 that is left in the buried remains. Since the half-life of carbon 14 is only 5,700 years, this clock will be reasonably accurate only up to about 25,000 years. Recently the Chicago investigators made an interesting test to check their method. They obtained two samples of wood from Egyptian tombs: one from the tomb of Sneferu at Meydum, the other from the tomb of Zoser at Sakkara. Archaeological evidence indicated that both samples were about 4,600 years old. The carbon 14 measurement gave an age that agreed with this within the statistical counting error—a remarkable demonstration and a well-executed piece of scientific work.

Still another possible clock is the isotope potassium 40. This isotope may decay to calcium 40 or to argon 40 (*see page 16*). Too little is known about its half-life, however, to make this clock usable at the present time.

ULTIMATELY the most interesting question to be answered by our radioactive clock is: How old is the earth itself? Older estimates have varied from the 17th-century calculation of the Irish Archbishop James Ussher that the earth was formed at nine o'clock on the morning of October 12, 4004 B.C., to the almost equally specific figure of 1,972,949,048 years arrived at by the ancient Hindus. The Hindus, oddly, were in the right order of magnitude.

The oldest rocks that have been reliably dated are about two billion years old. But obviously there is little hope of arriving at an accurate figure for the age of the earth by direct measurement of the age of any mineral, for it can never be ascertained from such evidence alone how close to the beginning of the earth's time that particular mineral was formed. As more minerals have been measured, older and older ones have been found, and it is known that there are rocks more ancient than those dated two billion years ago.

A more direct and at present the most reliable method of arriving at the age of the earth is the study of the ratio between lead 206 and 207, daughters of uranium 238 and 235, respectively, in lead ores occurring in various parts of the earth. As we have noted, because of the difference in their half-lives the ratio of U-235 to U-238 has changed during the earth's history. There was more U-235 in a gram of uranium in the past than there is today, and the ratio can be calculated for all times in the past. In the discussion of the thorium and uranium clocks, it was pointed out that the proportion of the various isotopes in common lead was almost constant. But it is not quite: actually "common" lead is made up of a "primeval" lead, inherited by the earth at its beginning, and very small additions of daughter lead from the thinly distributed uranium and thorium that exists through the earth's crust. These small additions vary with the age of the common lead. Using these facts

and comparing the proportions of lead 206 and 207 with lead 204 in a number of samples of lead ore of various ages and locations, the British geologist Arthur Holmes has computed the probable age of the earth at 3.35 billion years. This value appears to be the most reliable yet obtained. As the half-lives of U-238 and U-235 are determined more precisely, and as more isotopic analyses of lead are made, the figure may be modified, but it will probably not change very much.

IF THIS be taken as the age of the earth, how much older is the universe? Twenty years ago astronomers, led by the British cosmologist James Jeans, were in favor of the "long" time scale, reckoning the age of the universe as some thousands of billions of years. The discovery of the "red shift" in the light from distant galaxies, which led to the expanding universe theory, and work on the dissolution of galactic clusters, recently summarized by Bart Bok of Harvard University, have tended to shorten the time scale in the minds of most astronomers. In general it seems that the astronomers now are more conscious of the youthfulness of the universe than of its antiquity. Their estimates today are of the order of two to three billion years.

Geologists and radiochemists believe that through the study of the present abundances of unstable isotopes and estimates of their probable abundances in primordial times, they may be able to determine a limit for the age of the universe. If all the universe was created suddenly at a certain point in time, presumably all of the nuclear species now known, both natural and artificial, and many more besides, would have been formed in the process. This time of creation of atoms, if indeed such an event occurred at a single time, has been called "nucleogenesis." The present evidence seems to place nucleogenesis only a short time before the origin of the earth, three billion years ago.

The fact that we now have well-defined limits to the age of the earth, and even some suggestion of the age of the universe itself, brings us face to face with the hardly avoidable consideration that the material universe was born in a violent event at a time in the not too distant past. Thus our radioactive clocks, by introducing calculable time, however great, into the history of the earth and the universe, give a reality to events which was not present when they were considered to have happened vague "eons ago."

P. M. Hurley is assistant professor of geology at the Massachusetts Institute of Technology.

MILLION YEARS	GEOLOGICAL UNIT OF TIME			EVENTS	LEAD-RATIO CONTROL POINTS (MILLION YEARS)	MAGNETITE-HELIUM RATIOS (MILLION YEARS)	STRONTIUM-RUBIDIUM RATIOS (MILLION YEARS)
0	CENOZOIC ERA	CENOZOIC PERIOD	PLIOCENE EPOCH	Man appears			
			MIOCENE EPOCH	Mammals at peak Grazing types spread		17, 15, 15, 21	
			OLIGOCENE EPOCH	Mammals evolve rapidly Great apes		45	
			EOCENE EPOCH	Modern mammals appear.		46, 43	
			PALEOCENE EPOCH	Archaic mammals dominant	58	53, 51, 75, 51, 50	
100	MESOZOIC ERA	CRETACEOUS PERIOD		Dinosaurs, pterodactyls, toothed birds reach peak, then disappear. Small mammals. Flowering plants and hardwood forests			
		JURASSIC PERIOD		Dinosaurs and marine reptiles dominant		117, 120, 100, 120, 102, 132, 132	110, 150, 100
		TRIASSIC PERIOD		Small dinosaurs. First mammals. Conifers and cycads dominate forests		169, 158, 174, 165	
200	PALEOZOIC ERA	PERMIAN PERIOD		Continental uplift and orogeny	215		
		PENNSYLVANIAN PERIOD		Reptiles and insects appear. Spore-bearing trees dominate forests.		200, 205, 200, 225, 215 245	
		MISSISSIPPIAN PERIOD		Climax of crinoids and bryozoans.	255	240, 245	
300		DEVONIAN PERIOD		First amphibians. Brachiopods reach climax. First forests.		240 340 365, 340	300, 280, 200, 240, 300, 540, 270, 450, 540
		SILURIAN PERIOD		Widespread coral reefs. First evidence of land life	350	375	
400		ORDOVICIAN PERIOD		Invertebrates increase greatly. Trilobites reach peak differentiation.	440		
500		CAMBRIAN PERIOD		First abundant fossils. Marine life only. Trilobites and brachiopods dominant.			
	PRE-CAMBRIAN					550, 500, 550, 620	

HISTORY OF THE EARTH in comparatively recent geologic times has been classically worked out by the sequence of rock layers. This sequence is now supported by measuring the products of radioactive processes in the rocks. Three columns at the right give the results of such measurements.

SEEING LIGHT AND COLOR

One of our most familiar sensory experiences is perhaps the most difficult to define. The study of it requires the application of physics, physiology and psychology

by Ralph M. Evans

MOST of us feel quite sure that we know what is meant by the term color. We could all give some sort of definition of it, although we would not find it easy. We are likely to wind up with a pretty vague description of something having to do with light and objects.

The reason for the difficulty is not far to seek. What we call color is a purely mental effect. It takes place only in our minds, and we have no words to describe anything purely mental. It is the same with all of the other senses. A pain cannot be described except to say that it hurts, nor a sound except that it is loud or soft, high or low, complex or simple. To try to get deeper and describe what a sound *is* results in vagueness, again because there are no words.

In the 500 most frequently used words in the English language, according to the Thorndike-Lorge word counts, there are only 15 related to vision in any way. Of these only five are concerned directly with color. These are the words "color," "light," "white," "green" and "red."

Accordingly we are considering a subject which is not easy to put into words and which contains many philosophical problems too complex to attempt to present. Fortunately it is possible to illustrate some of the examples.

Statistics tell us that in this country less than half of one per cent of the men and practically no women are seriously color blind. A few people with anatomical difficulties may never see any colors at all, but this is rare. Some eight to 10 per cent of men, however, have comparatively poor ability to distinguish colors, and among persons with good color perception not all see colors alike, even in the pure colors.

Some of the apparent mysteries of color are fundamental to the way we see everything, not just color. Vision is perhaps the most wonderful fact in our lives. Color cannot be understood without some basic knowledge of its characteristics.

Let us first consider form vision as distinct from color vision. When we look at a natural scene we see certain objects spread out in a definite arrangement in space. For each of these objects an approximate size, distance, shape and color can be given. If we analyze our thoughts carefully, we find that around each thing we call an object, there is an abrupt change in the nature of the light that reaches our eyes. The closed or partially closed outline formed by this more or less abrupt change in light is considered as meaning that this is the edge of some actual thing in the scene. We recognize this outline and other visible characteristics and give the thing a name—say we recognize it as a "tree." This recognition of the shape of objects is called form vision. In a sense it is a more important type of vision than seeing the color red or green, since complex seeing is *based* on form recognition. So it is worth while to spend a little time on analyzing how you decide that this is a tree.

Consider the tree drawing on the opposite page. Here it is fairly obvious that the concept of tree develops entirely through the recognition of the outline: there is nothing else present in the picture. A little thought will show, however, that an outline is not sufficient to make us see a tree. We have to know what a tree is first.

If we know what the object is, only a suggestion or two is necessary to make it possible for us to see it. In fact it is not necessary that even the outline as such be shown. The shadow alone, as in the drawing showing the shadows of block letters on the opposite page, is usually enough to evoke at least some concept of the whole figure.

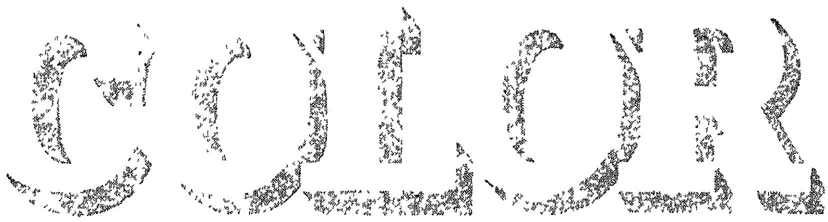
Seeing form, therefore, is partly a matter of outline but also, to a great extent, a matter of imagination. The same is true, to a lesser extent, of seeing color. When we associate a color very strongly with a particular object, we tend to assume that the object has the same color over its whole area, even though it may not have, and this is the way we see it, unless there is definite evidence that the color is not the same all over. This is partly because we don't look carefully and partly because we believe it so strongly.

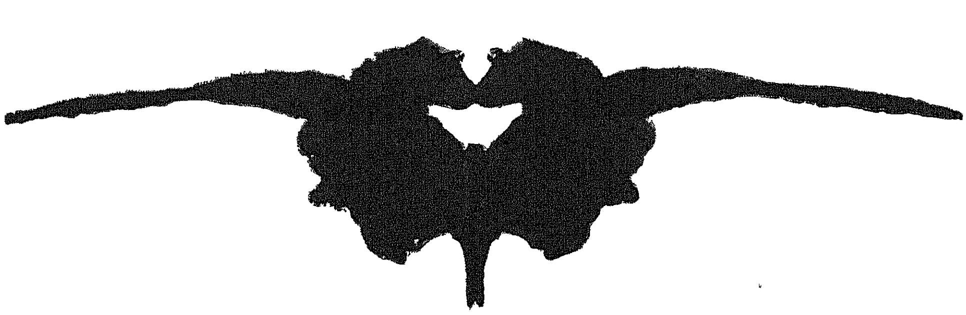
IN COLOR the nearest parallel case to form vision consists in seeing an object color in spite of conflicting evidence from reflections, transmitted colors, or sometimes even of colored illumination.

The light, our eyes and our mind are the three phases of color. Each of them enters into every ordinary situation in which color is seen. The three sciences to which these three phases relate are. physics, which deals with the nature of the light reaching the eye; physiology, which deals with the response of the eye and its transmission to the brain; and psychology, which deals with the mental image so produced. There is a fourth science known as psychophysics dealing with a combination of the three. This science concerns itself with laws that relate the physical nature of the light to the repeatable and measurable effects produced. In practice the boundaries between these phases are about as sharp as usual in related sciences.

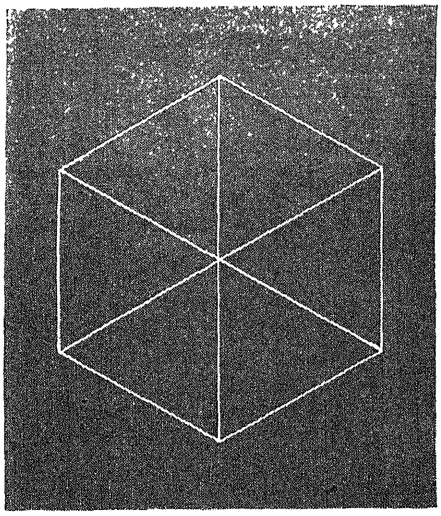
The problem is to explain how matter and energy, the "real things" in the domain of physics, produce different effects on people. Because of differing past experiences, if two people do not *look* for the same thing they do not see the same thing. The science of physics, however, states flatly that the light striking the eyes of two people looking at the same scene from the same position is the same in quality.

What is meant by "the same quality"? Suppose we consider one small beam of light striking the eye. Physics tells us

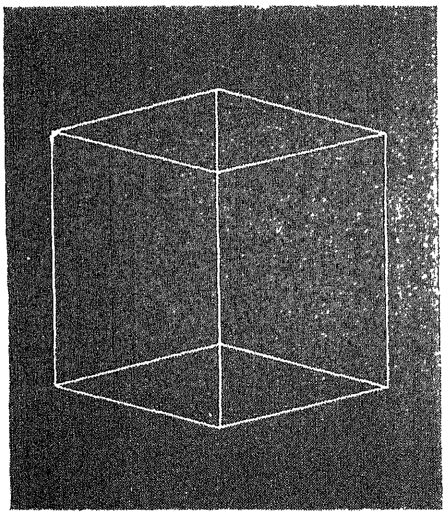




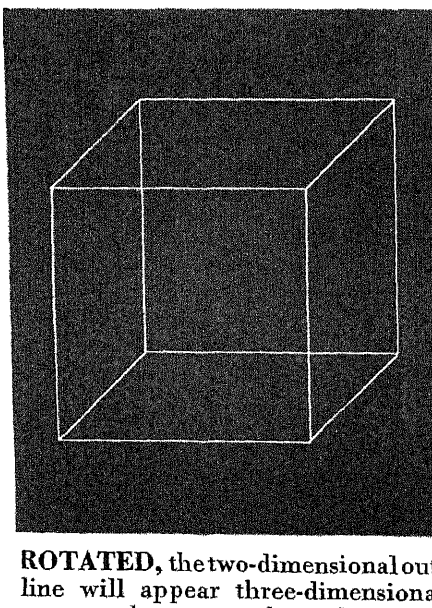
FORM VISION is based on outline and experience. The drawing at the top of this page is obviously a tree. Yet to a person who had never seen a tree it would be meaningless. Even outline is not essential to form vision. The block letters in the center of the page are not strictly outlined. Shadows are sufficient to make them apparent. The ink blot at bottom represents only an ink blot, but experience causes us to see many other things in it.



CUBE seen from one corner through one eye will appear to many as a two-dimensional drawing with six sides.



TILTED forward, the same transparent cube will represent to more people a three-dimensional object.



ROTATED, the two-dimensional outline will appear three-dimensional to even larger number of people.

that if this light is passed through a glass prism it is spread out into a color spectrum. This may be taken to mean that the beam of light is made up of a mixture of different kinds of light, which are separated in the prism by being bent in slightly different directions. The eye sees these differences as colors. Physicists identify them as differing wavelengths of energy, and measure them in terms of Angstrom units. The visible wavelengths range from about 4,000 Angstrom units, at the blue or violet end of the spectrum, to about 7,000, which is seen as red These numbers describe the kind of light independently of how it looks to an observer, and we need them as a reference point because of differences in seeing. A given wavelength, for example, may be seen under certain conditions as green and under other conditions as yellow or blue.

For the physics of color this is practically the end of the story Light from different sources and objects differs in the amount of each kind of wavelength present, and this may all be described by a curve indicating the amounts of the various components. The only other way in which two light beams may differ as far as the eye is concerned is in the direction from which they arrive. Direction, quality and quantity, therefore, are the characteristics of light before it has entered our eyes. The physiology of vision begins where physics ends—at the point where light enters the eye.

THE EYE, like a camera, has a lens at the front which bends the rays arriving at its surface so that light from each point of the object is focused at a point at the back of the eye. All the points taken together form an image of the scene. It is often assumed that in effect the mind looks at this image in the back of the eye and thus sees the scene out front, but this is a perfectly ridiculous notion. What actually happens is that the image affects some six or seven million nerve fibers that are sensitive to light. Each fiber gives off an electric current through a process which is perhaps photochemical in nature. The currents travel through a nerve cable to the brain and there produce in a fantastically complex manner some sort of replica of the image. That this brain image has any direct relationship to what we think of as a photographic image, however, is exceedingly unlikely.

There is no simple way of describing the action of the eye in terms of its reaction to various kinds of light under various circumstances. A statement of the mere physical characteristics of a scene does not describe its appearance to the eye with any degree of accuracy. The image is influenced by what the eye has seen just previously, by the effects of parts of the image upon one another and by the effect of the total image upon the appearance of its parts. For example, a patch of color with approximately the same spectral distribution as noon sunlight is seen as blue when it is surrounded by yellow. When the surrounding area is purple, the central patch appears yellowish green. Again, if it is surrounded by green, the center will be seen as pink. This effect is known as simultaneous color contrast The surrounding areas also affect the brightness as well as the hue of the central area. Such effects are not restricted to directly neighboring areas, they may occur over all parts of the field of vision.

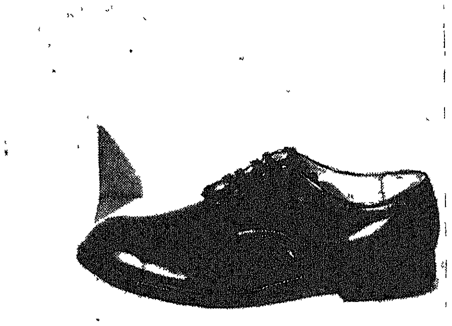
The carryover from one image to another is illustrated by this experiment. If you stare for 15 or 20 seconds at any clearly defined small area of color and then suddenly shift your gaze to a medium gray card, you see an "afterimage" of the first area The form of the afterimage is the same as the original, but its colors and brightnesses are different. The lighter parts are now the darker and *vice versa*, and the colors are complementary —for example, blue becomes yellow and green becomes pink.

There is another phenomenon, the exact opposite of simultaneous contrast, known as the "spreading effect." Ordinarily, simultaneous contrast should lighten the colors next to black. But if small, repeated areas in a design are surrounded by narrow black lines, they look darker. Conversely, small white lines around the same areas make them whiter. This effect is seen quite often in daily life if one looks for it. Any small area of color such as a block letter immediately becomes darker if a black line is drawn around it; its color will mix with whatever color is used to draw the line. The effect, which has not yet been satisfactorily explained, is purely visual

NOW ALL these effects are what you might call properties of the eye itself. They occur whenever these conditions are present, and are effectively the same for all people. They lie in the field of physiology, they do not depend on individual experience in any way.

In looking around us, we see not patches of light but real objects in a real world. And this brings us to the psychological aspects of vision.

Let's start with the flat statement that when you "see" an object in front of you at any distance beyond your reach, you actually see not what *is* there but what you think is there. And this is not meant in any abstract philosophical sense. Consider the series of three drawings at the left. The first shows a six-sided figure with radial lines from the center to the corners. This is a perfect drawing of a transparent cube as seen with one eye looking directly at one corner. Many people, however, will see it only as the two-dimensional drawing which it really is. If we tip the cube, as in the second draw-



SHOE standing by a cube makes it possible for the viewer roughly to estimate the apparent size of the cube.

ANOTHER shoe provides basis for estimating another cube to be smaller than the one that appears at left.

COMPARISON of shoes shows that one is size 52. Cube was thus judged by experience rather than by reality.

ing, more people will tend to see it as a cube, or at least as a drawing of a cube; and if we rotate it slightly, as in the third drawing, most people will see it as a cube built up out of 12 white wires rather than as a drawing at all.

Many reasons can be given for this change in attitude. All three of the drawings are two-dimensional, and yet you change from seeing the drawing as a design to seeing it as a reproduced object. You see what you consider the most likely meaning of the drawing. If you believe it is intended as design, you see it that way; and *vice versa,* if you feel that it represents a cube you change to that way of seeing it. And you see the lines as a cube not so much because they are *like* a cube but because a cube is the nearest thing in your experience to what you see in the diagram.

Our vision is so highly trained as to make all our other skills comparatively crude. Practically every waking moment, since we first tried to reach out and touch a bright something in front of us, has been devoted in part to learning to see. The net result, by the time we reach maturity, is amazing, but few of us ever have occasion to consider it objectively. Indeed, the very fact that most of us are unconscious of this skill makes its properties surprising and not easy to understand.

As Adelbert Ames of the Dartmouth Eye Institute puts it, "The things we see are the mind's best bet as to what is out front." They represent the assumption we should have to make if we were to take some action toward the objects.

A more dramatic illustration than the drawings is the series of three photographs at the top of this page. In the first you see a familiar object, a shoe, along with a not so familiar cube. Although you do not know the exact size of the shoe, you have a fair concept of its length, and accordingly, you have an idea about the size of the cube. In the second photograph you note that this is a different shoe and a much smaller cube. There is nothing unusual to you about either picture because you have *assumed* them as usual. But when you look at the third photograph you immediately readjust your thinking drastically. You now realize that you chose the wrong class of objects as the standard of measurement. You measured the cubes by the shoes, instead of *vice versa,* simply because your assumption about the size of the shoes was the safest you could make. There was nothing in your experience to suggest that one of the shoes might be size 52!

Seeing, therefore, is as much a matter of experience as of physics or physiology. It is always based in part on assumptions. We see what we believe we are looking at. Our mental pictures are our own. They are not necessarily shared either by others or by the objects themselves.

SUPPOSE you were suddenly confronted by an entirely unfamiliar object, what would you see? The answer is quite simple: you would see it as similar to a possible something you had encountered before. Given a particular scene, you do your best to see the objects as you really believe them to be. On the whole you do a very creditable job. Occasionally, however, the situation is too much for you and the result does not jibe with the facts. Or conversely, and more importantly, as the result of your experience you may see something correctly even when the physical facts of the situation are misleading or confusing.

It is interesting to review a few cases where the mind sees correctly and instantly things which from the physical standpoint are quite complex. If a clear colorless glass object is placed in front of a colored surface, you see the color of the background through it. The glass seems to have the color of the background. If the situation is apparent enough, however, you may distinguish the clear colorless glass from the color of the light reaching your eyes. You see this even though the situation is obscure. But in order that anything be "seen" in the ordinary sense of the word, it must tie in with an experience in some way.

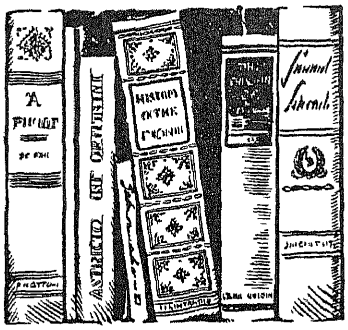
Once you do see a particular property of an object, however, you then proceed to make a fairly obvious but usually unconscious assumption about it. You assume that, in the absence of other indications, these properties hold over the whole of the object. If they do not, you may get rather badly fooled, but in everyday experience it is a fairly safe assumption.

One of the most remarkable abilities the mind possesses is that of seeing two colors at the same place simultaneously. The image of a red traffic light, for example, may be seen reflected from a glossy blue surface in such a way that the patch appears both red and blue at the same time. There has been much controversy over this phenomenon from the time of Hermann von Helmholtz. Three possible explanations have been proposed. You may see simply the mixture of the two colors according to the simple laws followed by color. This is the result which would be predicted by the psychophysical approach. Or you may actually see both colors simultaneously and separately. This is the result suggested by the work of some psychologists. Or you may just imagine that one color continues across under the other without looking at the color at all. This was Helmholtz' suggestion; he called it "unconscious inference." There are examples which appear to support each of the three cases. Reflections are of almost constant occurrence in the world around us. It is their very familiarity which is probably the key to the whole matter. We are so accustomed to seeing the phenomenon and knowing the facts it presents that we have simply learned to recognize the true meaning.

"The eye is blind to what the mind does not see." This old Arabian proverb could have been written by any modern worker in the field of vision. Seeing is not simply a matter of the physics of the light reaching the eye, nor of the properties of the eye which it strikes. It depends on the mind and the experiences that have shaped it.

Ralph M. Evans is head of the Color Control Department of the Eastman Kodak Company.

BOOKS



Another contribution to the rapidly growing literature of mathematics and human behavior

by J. L. Walsh

HUMAN BEHAVIOR AND THE PRINCIPLE OF LEAST EFFORT: AN INTRODUCTION TO HUMAN ECOLOGY, by George Kingsley Zipf. Addison-Wesley Press ($6.50).

THERE has been a striking increase recently in the attention devoted to the mathematical study of human behavior. We have, for instance, outstanding work by A. J. Lotka on population analysis, by John von Neumann and Oskar Morgenstern on the theory of games, by H. T. Davis on "econometrics," by John Q. Stewart on "social physics," and by Norbert Wiener on "cybernetics." These efforts, in part simply objective studies by inquiring minds, are also occasioned by the immediate and pressing need for practical decisions in social affairs.

It would be rash to prophesy that a new science of human behavior will now evolve along the lines of the history of mechanics, but it would be foolish to ignore the lessons of that history. We recall the pattern of the evolution of mechanics: Tycho Brahe (1546-1601), an astronomical observer of great skill, made numerous observations of the motions of the planets that were used by his pupil Kepler (1571-1630) to formulate the fundamental laws governing those motions, and Newton (1642-1727) in turn founded the science of mechanics to explain those laws. Certainly it is reasonable to expect that laws in social science, subject to revision and obsolescence, may similarly be established. A skeptic who totally doubts this possibility will have few companions among open-minded, intelligent inquirers who have considered modern writings.

The mere organizing of numerical data in social relations is valuable work; only thus can norms be established and abnormalities recognized. To consider an analogy in medicine, fever in a human being is evidence of an unusual condition, and is significant whether or not a complete diagnosis and an artificially induced cure are possible. In the present state of the social sciences, an investigator should not despise the use of models, especially simplifications of and abstractions from concrete situations. In the mathematical study of the motion of a single planet we often ignore the effects of other planets, and in the study of the motions of the entire solar system we often ignore the effects of other suns. The investigator should not fear the charge of "arguing by analogy." Perhaps the truest of the world's wisdom is embodied in parables—indeed, perhaps all wisdom consists in parables, including analogies and abstractions.

George Kingsley Zipf, University lecturer at Harvard University, started writing on the problems of social phenomena a quarter of a century ago, when it occurred to him as a philologist "that it might be fruitful to investigate speech as a natural phenomenon, much as a physiologist may study the beating of the heart, or an entomologist the tropisms of an insect, or an ornithologist the nesting-habits of a bird. That is, speech was to be regarded as a peculiar form of behavior of a very unusual extant species; it was to be investigated, in the manner of the exact sciences, by the direct application of statistical principles to the objective speech-phenomena." Since then Zipf has extended his studies into numerous other fields of social relations. His book is a comprehensive treatment of the work done by himself and his students, and by other investigators in the same field.

Zipf's thesis is that the activity of every individual will tend to be governed by a Principle of Least Effort, where effort, or work, is averaged over a period of time and based on an estimate of future probabilities by the individual. Zipf has gathered and analyzed large amounts of statistical data bearing on this principle and on biosocial phenomena in general. He has shown that in a great diversity of fields the principle unifies and explains the observed actions of individuals and of groups. We shall consider here some examples from his discussion.

Zipf is at his best, and indeed without a peer, in the statistical study of language. Let us examine some results in his study of word frequency. In a sample of the writing of an individual, each different word will occur a certain number of times; let us call this number the frequency, f, of that word. The frequency of each word is then given its relative rank, r. The rank of the most frequently used word is 1, of the next 2, and so on. The remarkable finding is that in any reasonably sized sample of an individual's writing the product of the frequency and rank of any word—f times r—is always approximately constant, regardless of how the word ranks. For example, Miles L. Hanley and his associates compiled a word index to James Joyce's novel *Ulysses*, and M. Joos made a statistical study of these words. The novel, 260,430 words long, has 29,899 different words. The 10th most frequent word occurs 2,653 times. Multiplying r (10) by f (2,653), we get 26,530. The 50th most frequent word occurs 556 times. Here r times f equals 27,800. The 100th most frequent word occurs 265 times, and $r \times f = 26{,}500$. The 1,000th most frequent word occurs 26 times; $r \times f = 26{,}000$. When the frequency and rank of each word in *Ulysses* are plotted on a coordinate graph, with the values of r laid off horizontally and the corresponding values of f vertically, the result is the curve A in the top chart on the opposite page. The scales of both r and f are made logarithmic, so that this curve can be readily compared with the ideal curve C. The latter is a straight line sloping downward to the right at an angle of 45 degrees to the horizontal, that is to say, is a straight line with a slope of minus one, which represents the equation $r \times f =$ constant. The agreement of the empiric curve A with an ideal curve of type C is too close to overlook or ignore.

This law of word frequency goes back at least to the work of a Frenchman named J. B. Estoup in 1916. The law is so surprising that many have questioned it. Indeed, the data from *Ulysses* plotted as curve A were compiled by skeptics who originally had expected to show that the law did not hold! Zipf, who has long investigated the law, adduces other evidence to support it in his book. For instance, curve B in the same chart on the opposite page is based on a study by R. C. Eldridge of word frequencies in U.S. newspapers. His combined samples had 6,002 different words in a total of 43,989 running words. Here again the closeness of the empiric curve B to the ideal curve C is striking. The same results appear in the analysis of numerous other samples of language: in Chinese, Gothic, Ælfric's Old English, Old High German, Pennsylvania Dutch, Yiddish, modern Hebrew, Norwegian, several dialects of American Indian, and numerous English writings, including *Beowulf*, Shakespeare's *Hamlet* and T. S. Eliot's poetry.

The cumulative weight of this mass of evidence is convincing. There are divergences from the ideal that require some explanation. Thus the noticeable steps at the bottom of curves A and B

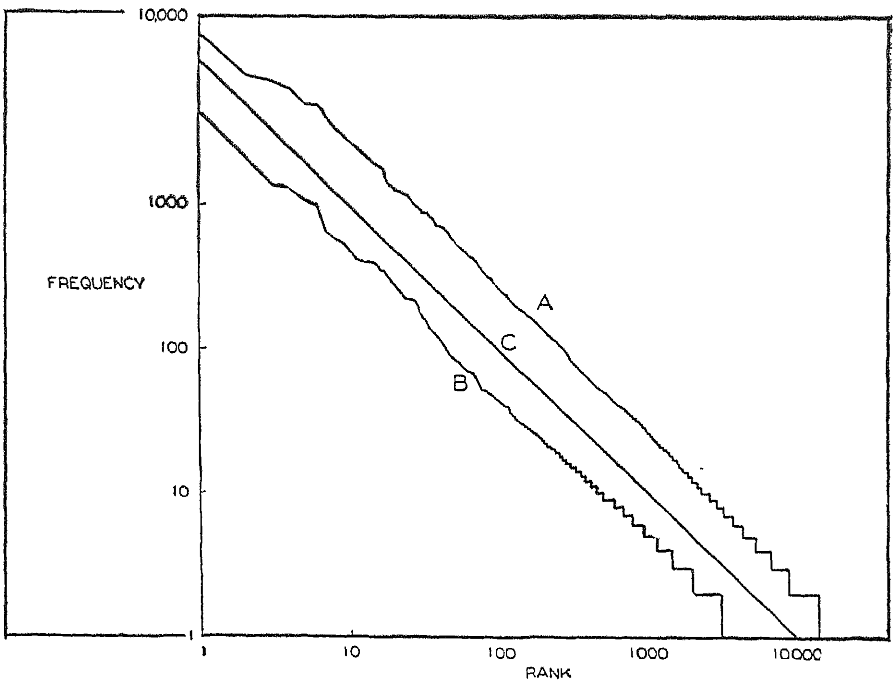
are occasioned by the fact that frequency f and rank r are necessarily whole numbers, a large number of words occur just once, and a large number just twice. Other related questions suggest themselves. What is the optimum size of a sample? Should "house" and "houses" be considered the same word or as different words? Should "brother-in-law" be counted as one word or three? How does the length of a word compare with its frequency? How do formal and informal writings differ? Does a child's language exhibit the same law as an adult's? What is the characteristic word-distribution of a schizophrenic? Zipf discusses these questions with insight, and explains the departure of some curves from the norm.

As a model to aid in discussing the rank-frequency law and the Principle of Least Effort, Dr. Zipf considers an artisan at his workbench, with a variety of tools arranged in succession on a straight rack extending directly away from him. The artisan must perform certain assigned jobs, fabricating a large number of articles with the tools and raw materials placed at his disposal. He is at liberty to modify his tools by altering their size, shape, stowage and usage, and also by discarding old tools and manufacturing new ones. We require him, however, to minimize his total work (this is the least-effort principle), and this work includes planning, use of tools and modification of tools.

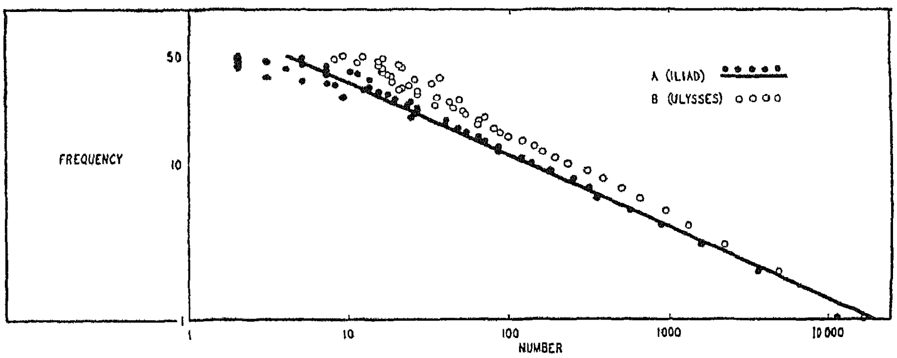
If we disregard the work of applying each tool to the raw material, which can be considered constant, the problem reduces itself to the movement of the tools from their places on the rack, and any modifications of tools that seem to the artisan desirable. The work of moving each tool is proportional to its mass m, its distance d from the artisan, and the relative frequency f with which it is used. Thus the work of using a single tool is equal or proportional to the product $f \times m \times d$, and the total work is the sum, W, of all the products. The artisan's problem is to minimize W, that is, to make the most economical arrangement and use of the tools.

Certain principles at once suggest themselves. The artisan will pack the tools as close together on the rack as he can, in order to minimize the distance d for any individual tool and for all tools beyond it. Close packing involves a reduction of the size of tools, especially of those near the artisan. He also tends to reduce the mass of each tool, to decrease the factor m. This "abbreviation" becomes especially important for a frequently used tool. Of course the most frequently used tools tend to become small, and the smaller tools tend to be those most frequently used. It is economical to redesign a small, frequently used tool so that it may absorb the jobs of heavier and less-used tools.

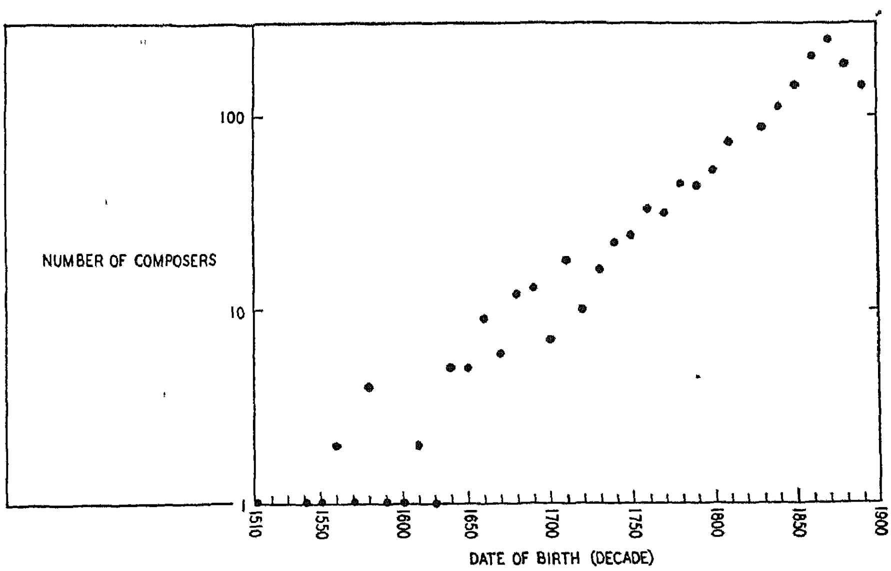
Now an artisan's use of tools is closely analogous to a writer's or speaker's use



STATISTICS OF LANGUAGE reveals a remarkable order in word frequency. Here the rank-frequency relation of words in Joyce's *Ulysses* (A) and in newspaper articles (B) is compared with theoretical curve (C).



MATHEMATICAL REGULARITY is also shown in this comparison between *Ulysses* and Homer's *Iliad.* Number of words used with various frequencies is plotted. The relation is consistently the same for both works.



CHAMBER-MUSIC VOGUE is plotted mathematically here. Between 1510 and 1870 the number of chamber-music composers increased exponentially. Sharp drop after 1870 may be due to decline in popularity of this music.

of words. To a remarkable degree the laws for the artisan are objectively verifiable for the writer and speaker. Thus long words tend to become abbreviated or replaced, and shorter words tend to be used more often. The psychologist E. L. Thorndike has observed that "we have found evidence that differences in frequency, even among words occurring less than two times in a million, are related to differences in number of syllables or of phonemes." Words, especially the shorter and more frequent ones, are often used in permutations with specific others. In the dynamic problem where words may change, there are in constant operation forces tending to design and introduce new words, to modify and give new uses to old ones, and to discard seldom-used words In a relatively static situation, these forces are in approximate equilibrium.

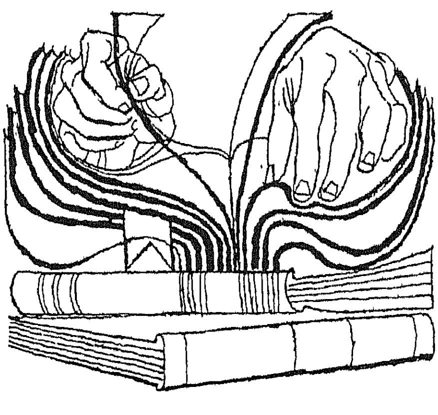
Thus while we have no syllogistic proof of the Principle of Least Effort, we do have a verification of the principle in the direct numerical study of language, in the fact that parallel laws concerning tools for the artisan and words for the speaker and writer can be rationally established from the principle.

The scope of the author's plan is so extensive that we can but mention some of the other topics he treats. In addition to the language of adults, he considers empirically and rationally the verbalizations of children, the origin of speech, the economy of sensation, intellectual rigidity, the biosocial aspect of organisms, procreation, culture, schizophrenia, dreams and art. He then proceeds from the study of the individual in society to the study of the social activity of groups, with reference to such diverse topics as the economy of geography, including the rank-size of cities, the rank-number of manufacturing establishments and shops, the movement of bus, railway and airway passengers, and the number of telephone messages, international and intranational cooperation and conflict; distribution of economic power and social status; prestige symbols and cultural vogues. The tool analogy continues to be illuminating throughout, and the rank-frequency law illustrated in the chart at the top of page 57 occurs again and again.

In a complicated and confusing wilderness Dr. Zipf has hewed paths, and indicated numerous others, of interest to the informed layman and of great significance to the present and future specialist. In a sense, this work so far serves mainly to suggest further unsolved problems. What, for example, is the scope of the Principle of Least Effort, and how should it be precisely formulated in diverse fields? How is mental effort to be measured, and what is the conversion factor with physical effort? In the tool analogy and in language, the system apparently tends dynamically toward a static condition exemplified in the curve for the rank-frequency distribution for words This distribution is rationally demonstrated in qualitative terms, but not quantitatively. Why, for instance, is the distribution linear, and why is the slope minus one? Opportunity is ripe for new Tycho Brahes, Keplers and Newtons!

J L Walsh, Perkins Professor of Mathematics at Harvard University, is president of the American Mathematical Society

THE BISMARCK EPISODE, by Captain Russell Grenfell The Macmillan Company ($3.00). An absorbing account of what was perhaps the most exciting and difficult chase in modern naval history. Only Nelson's pursuit of Villeneuve to and from the West Indies in 1805 covered greater distances than the 3,000-mile tracking of the *Bismarck* by the ill-



fated *Hood, Prince of Wales, King George V, Rodney, Ark Royal, Victorious, Norfolk, Suffolk,* shoals of lesser naval craft, and various aircraft. Even Admiralty headquarters, moored quite fast in London, joined in the chase (not always to advantage), freely dispensing the conjectures of its planners and coordinating scattered activities by wireless. The final kill came almost as an anticlimax to the dramatic hunt in which every available scientific resource, and every human resource of bravery, endurance, seamanship and shrewd guesswork combined to convert what started out as a disastrous defeat into a brilliant victory. Captain Grenfell's clear style is just right for this superb story and for imparting easily all of its complicated scientific and nautical detail.

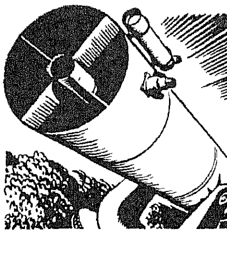
FLIGHT INTO HISTORY. THE WRIGHT BROTHERS AND THE AIR AGE, by Elsbeth E. Freudenthal. University of Oklahoma Press ($3.75). The chief virtue of Miss Freudenthal's account is its separation of facts from the nostalgia-laden myths surrounding one of the greatest advances in aviation history. A number of points regarding the Wright brothers' achievements are now firmly established. Their 12-second Kitty Hawk flight of December 17, 1903, was the first controlled flight ever made, Wilbur's record on the same day of a 59 second flight covering 852 feet was not equalled for years, though most of the world received the news with skepticism if not hilarious incredulity, the French characterizing it as "un bluff Américain phénoménal," for the actual construction of their beautiful plane and engine the Wright brothers were alone responsible, they were careful and original experimenters (their wind-tunnel experiments and tables were first-rate examples of scientific work), skilled technicians and superb pilots. It is, however, by no means clear that they appreciated, much less acknowledged, the contribution to aeronautical science and to their own success of their contemporaries, including their generous friend and supporter Octave Chanute. Nor did they seem to realize that the wing-warping control system from which they derived their wealth was so closely linked to, and so much the development of, the researches of other investigators that it was absurd for the Wrights, except as contenders for patents, to claim absolute priority for the theory and methods involved. In this phase of the history of science there is surely enough credit to go around, though the Wrights got the more tangible rewards. Unfortunately, as Chanute wrote them in 1910 when their claims were in controversy, they permitted their "usually sound judgment . . . [to be] warped by the desire for great wealth" From Miss Freudenthal's balanced account of their aviation exploits and business dealings, the Wright brothers personally emerge as a faceless, enigmatic pair, and her book suffers generally from a lack of life-giving detail regarding what must have been a most colorful train of episodes.

REGULAR POLYTOPES, by H. S. M. Coxeter. S. J. Reginald Saunders and Company, Ltd ($3.50). The early history of the polyhedra—geometrical figures bounded by portions of planes—is "lost in the shadows of antiquity." The famous five regular solids, three of which, together with other polyhedra, occur in nature as crystals, were studied by the Pythagoreans, by Plato, and, more exhaustively, by Euclid. Excavations on Monte Loffa, near Padua, have uncovered an Etruscan dodecahedron, showing that this figure "was enjoyed as a toy at least 2,500 years ago." A law of symmetry related to Haüy's crystallographic "Law of Relativity" asserts the impossibility of the "inanimate occurrence of any pentagonal figure, such as the regular dodecahedron": Thus while the tetrahedron, cube and octahedron are found as crystals, the dodecahedron and icosahedron cannot form crystals but need "the spark of life to occur naturally." Professor Coxeter of Toronto University, known for his revision of

Ball's *Mathematical Recreations and Essays* and for his papers on geometry, has assembled a treasure house of information on the two-, three- and four-dimensional polytopes In addition to examining thoroughly, with the use of both elementary and advanced methods, the properties of ordinary and multi-dimensional figures, Coxeter has enriched this volume by interesting innovations of his own, numerous cuts and plates, historical summaries, tables and a useful bibliography. Of the last-named Coxeter remarks that the listing of the names of 30 German mathematicians, 27 British, 12 American, 11 French, 7 Dutch, 8 Swiss, 4 Italian, 2 Austrian, 2 Hungarian, 2 Polish, 2 Russian, 1 Norwegian, 1 Danish and 1 Belgian, "provides an instance of the essential unity of our Western civilization, and the consequent absurdity of international strife."

IDEALS AND ILLUSIONS, by L. Susan Stebbing. Thinkers Library, Watts & Company, London (3 shillings sixpence). FRIAR'S LANTERN, by G. G. Coulton Thinkers Library, Watts & Company, London (3 shillings sixpence). Not the least welcome sign of economic recovery in Britain is the increase in paper supply, with correspondingly more generous allotments to publishers for new books and for the reprinting of many older books, long unavailable but still in demand. These inexpensive, compact little volumes, well bound and clearly printed, are in the Thinkers Library, an admirable series now being replenished, with new titles added. Susan Stebbing's essay, a constructive critique of the ideas, ideals and illusions men live by, written in 1941 against the dark background of the war, compares favorably with all that came from her devastating, lucid pen, from her uncompromisingly honest and perspicuous mind. ("In discussion with her," said John Wisdom, "one could not expect to sit about in warm air—a stiffish breeze was usually blowing.") The late G. G. Coulton's fable of two modern pilgrims transported, like the Connecticut Yankee, into the Middle Ages, is an odd but pleasant and richly learned diversion, by one of the most distinguished and also one of the crotchetiest scholars of our period.

FOUNDATIONS OF MODERN PHYSICS, by Thomas B. Brown. John Wiley & Sons ($5.00). A good descriptive account of the experimental foundation of a wide range of topics underlying the modern knowledge of atoms, molecules and nuclei. It uses a minimum of mathematics and would be suitable for a junior or senior undergraduate college course. Very little space is devoted to the revolutionary ideas of relativity and quantum mechanics, except where these are directly involved in some experimental subject under discussion.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

TELESCOPIC observation of the moon by amateur astronomers can be pursued at two levels. In the first, the novice examines the moon through the telescope he has just completed. He is thrilled by the splendor of his first magnified view of it, and astonished at the almost infinite variety of fine detail he increasingly discerns as he pores again and again over the brilliant image. Truly the moon is, as the astronomer Henry Norris Russell has said, "the finest of all telescopic objects."

Within a few weeks the new observer can identify the principal "seas" and mountain ranges of the moon. But then, after following it through one or two lunations, he may think the show is over and stop, hardly realizing how much further he could go. Some amateurs, however, continue observing the moon and studying its map. These enthusiasts soon enter the realm of the selenographer, to commune with a limited but world-wide circle of inveterate observers.

At this stage, amateur selenographers seek a detailed map of the moon, but find that Walter Goodacre's famous map of the moon is no longer available. Luckily there is another great map of the moon even larger than Goodacre's: the Wilkins map, drawn 25 feet in diameter by H. P. Wilkins, the director of the Lunar Section of the British Astronomical Association. It is reduced for reproduction to a diameter of 100 inches and is cut into 25 convenient sections 20 by 21 inches each. The Wilkins map is obtainable from its author at 127 Eversley Road, Barnehurst, Kent, England, postpaid anywhere for two pounds sterling, approximately $8. The 25 sheets constitute the most detailed map of the moon ever drawn.

The accompanying illustrations are full-size samples of one sheet of the Wilkins map. The larger represents 1/4400 of the entire lunar area, all of which is drawn on the same faithfully detailed, accurate scale. This area includes the 25-mile crater named Porter; the name was recently inked in by Mr. Wilkins as a lasting memorial to the late Russell W. Porter. The fine detail depicted on the map is exemplified in the smaller sample by the little circle above the terminal "o" in the word Tycho. This circle represents a lunar hillock only a little more than a mile in diameter; the tinier circle to the right of the "o" is therefore less than half a mile in diameter. A single dot might represent a feature the size of the Capitol at Washington, which would be about the limit of visibility in any telescope.

Represented on the Wilkins map, in addition to all the major features, are an unnumbered host of craterlets, crater pits, crater cones, clefts, ridges, light streaks (dotted lines), and a few spots designated as variable areas. These alleged variable areas are kept under observation, mainly by amateur astronomers, because they seem to some to undergo change.

Is the moon a totally dead world? This is an open question of long standing among astronomers. Apparent minor changes in the formations Aristarchus, Atlas, Eratosthenes, Kepler, Linné, Manilius, Pico, Plato, Theophilus, Tycho and a score more may or may not be real. In 1926, at the end of a discussion of this question, Russell, R. S. Dugan and John Q. Stewart stated in their textbook, *Astronomy*, that the consensus was that no real changes have been detected on the moon. In saying this, however, they do not dogmatize. They add that the disputed question is difficult to settle.

In a 76-page booklet entitled *Does Anything Ever Happen on the Moon?*, devoted wholly to this fascinating question, the planetary astronomer Walter H. Haas of Albuquerque, N.M., has pointed out that the moon has been greatly neglected by professional astronomers. One observer who saw changes on it had made far more extensive studies of the moon than had his professional critics. The booklet by Haas, a series of articles reprinted from *The Journal of the Royal Astronomical Society of Canada*, brings together widely scattered material on the

A section of Wilkins' 25-foot lunar map

The region of Tycho

study of lunar changes. There are several types of changes: permanent, irregular, periodic, and color changes

Is the darkening of some small spots in the crater Alphonsus, seen at each 29½-day lunation, due to vegetation, as W. H. Pickering believed? Are the changes in the crater Eratosthenes, to whose description Pickering devoted several articles in *Popular Astronomy* 30 years ago, real? What of the crater Linné, whose tiny white area appears to change in size, and what of Plato, where new craterlets seem to have appeared, and where mists were seen by Haas? In Tycho, Haas claims to have seen a curious, milky-looking luminosity on the east outer wall, strongly suggesting the existence of a lunar atmosphere. Some of these changes have been discussed in the periodical Haas edits, *The Strolling Astronomer*

To participate in the observation of fine detail on the moon and not merely gaze at it, the amateur needs a telescope of six-inch aperture or larger, a minutely detailed map, and persistent effort. He soon learns to recognize many of the small details and comes to think of some of them almost as his own possessions.

The Wilkins map, now in a second, revised edition, was compiled from three sources: photographs taken with the 100-inch telescope, drawings by eminent lunar observers, and its author's observations at the eyepiece Since 1909 Wilkins has observed the moon with telescopes of various apertures, chiefly with a 12½-inch reflector. Goodacre has pointed out that the details which can be obtained on photographs with the 100-inch telescope barely tax the powers of an amateur-size instrument of about that aperture, in his own case a 10-inch refractor.

A NEW BOOK, *Engineering Optics*, by K. J. Habell and Arthur Cox, both formerly employed by the British optical firm of Taylor, Taylor and Hobson, Ltd., has just been published by the Pitman Publishing Corporation, New York, N.Y. It deals with the principles of optical methods in engineering measurement. The opening two chapters give the theoretical background for understanding the subsequent chapters on light and illumination in optical instruments, on microscopes, telescopes, optical projection and profile microscopes, and on miscellaneous optical methods. In all these the emphasis is on practical applications. for example in the contour projector, the profile microscope, the alignment tester. At $7.50 its addition to the amateur's library is well justified if his interest is mainly practical.

PLEASURE in the successful attainment of a high degree of precision is believed by some to be the force that keeps the amateur telescope maker going back to his optical work when he should be using the telescope he has just made. If this really is the underlying motivation, it would explain the fact that the lover of precision optics is usually a lover of any kind of precision work.

The most exacting and difficult of all high-precision work is thought by many to be the construction of a ruling engine, and with it the actual ruling of diffraction gratings, especially those of the larger sizes. For some months past there has been an unprecedented ferment in the small and very limited world of the ruling engine. Whereas all the world's demand for diffraction gratings has until recently been satisfied by two or three makers, that demand has increased so rapidly since wartime that several laboratories are now hard at work building new ruling engines for making more gratings. The chief cause of the greatly increased demand is the widening "discovery" by industry that spectrographic analysis is more rapid than chemical analysis, and that grating spectrographs have greater advantages than prism spectrographs; also, in the realm of physical science, the need for large gratings having high resolving power for use in basic research.

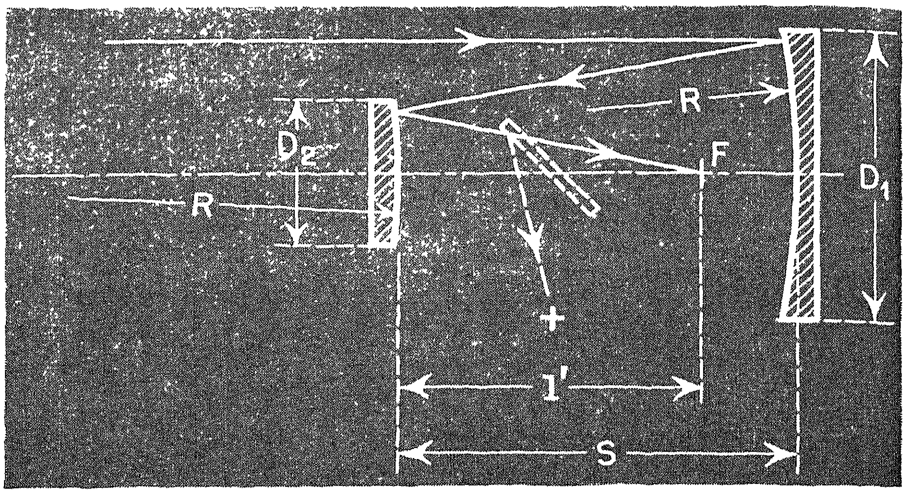
In a monumental article on "The Production of Diffraction Gratings," published in the June number of the *Journal of the Optical Society of America*, George R. Harrison, Dean of Science at the Massachusetts Institute of Technology and editor of that journal, discusses the present status of grating ruling.

Two-inch gratings, such as are used in many spectrographs of the industrial type for chemical analysis, can be produced almost on demand by any of a number of engines now in operation.

Four-inch gratings can be produced by ruling engines at Johns Hopkins University, at the Mount Wilson Observatory, by M. Siegbahn in Sweden, and by Baird Associates in Cambridge, Mass. The Bausch and Lomb Optical Company of Rochester, N.Y., and the Jarrell-Ash Company of Boston, Mass., also are expected to operate within a year on gratings of this size.

Six-inch gratings can be produced at Johns Hopkins University fairly regularly and at the Mount Wilson Observatory occasionally, with Siegbahn, and Bausch and Lomb, probably coming in soon as sources, and perhaps Baird Associates and the Jarrell-Ash Company.

Eight-inch gratings are not at present available anywhere on earth. There is some hope of their production by Siegbahn, possibly by Bausch and Lomb, by Johns Hopkins University and M.I.T. Gratings of this large size are needed for research in pure science, but very little if at all in industry. It is on this size that the rivalry to get into production first is greatest. It is hoped by the more optimistic that 1949 will see the actual beginning of ruling by several large engines, some of them newly designed on principles that depart from the conven-



Scheme of the "wyldalkirk"

tional engines of Rowland. (These are still in operation at Johns Hopkins University, and still produce virtually all the larger gratings made in this country.) Since grating ruling is beset by many problems, none of the friendly competitors in the grating race has issued a schedule of production. None has even promised to produce gratings. This is not evidence of faintheartedness, but of wisdom born of others' experience.

EYEPIECES made by Sir William Herschel with tiny lenses only 1/45-inch in diameter, one third that of a pinhead, that gave a magnification of 10,000 diameters on a six-inch reflecting telescope, were described in this department last August. One modern writer was quoted who wondered how a present-day optician would proceed if required to duplicate such extremely small lenses.

It has been learned that several years ago H. E. Dall of Luton, England, succeeded in slightly surpassing Herschel. The respective diameters are: Herschel .02 inch, Dall .016 inch. The foci are: Herschel .0111 inch, Dall .010 inch. Even when used alone, Dall's lens gives a magnification of 1,000 diameters.

THOSE who make Cassegrainian telescopes must first make a concave spherical primary and alter it to a paraboloid, and then make a convex spherical secondary mirror to another radius of curvature, and at still greater pains alter it to a hyperboloid Some years ago Dall, and also Alan R. Kirkham, decided that this method demanded much unnecessary work, and that it had been practiced for two centuries only as a bad habit. So they left the convex mirror spherical and, by altering the concave mirror to an ellipsoid, obtained as good a telescope as the Cassegrainian. This "Dall-Kirkham" telescope, sometimes misnamed "the spherical secondary Cassegrainian," is now a firmly established timesaver.

The amateur designer James H. Wyld of Denville, N. J., has now proposed a modification for which the name "wyldalkirk" is suggested, representing Wyld's special case of the Dall-Kirkham telescope. "No one," he writes, "seems to have thought of the *equal-radius* Dall-Kirkham. The advantage that I see in it is the reduction in the number of grinding tools. The secondary, having a radius equal to that of the primary, would be used as a subdiameter grinding tool for the primary, or as one of the grinding tools, a larger tool might also be used for smoothing.

"The primary," he continues, "would be polished to a spherical figure, then used, as suggested by James G. Baker, as a test plate to figure the spherical secondary. Finally it would be figured 'flat' (null) by the Dall-Kirkham test, with the light source at the proper distance to give the right correction. Then the whole would be assembled and collimated.

"I've worked out the proper corrections, focal lengths and so on for several different designs."

No way is known to make fascinating reading of the bleak specifications that follow, except to telescope making enthusiasts To them they will be as interesting as they are significant.

In the table on the opposite page, unity is the radius of curvature of the primary and, therefore, of the secondary. All other dimensions, keyed by letter designation to the diagram above (which is not to scale), are multiples of that unit.

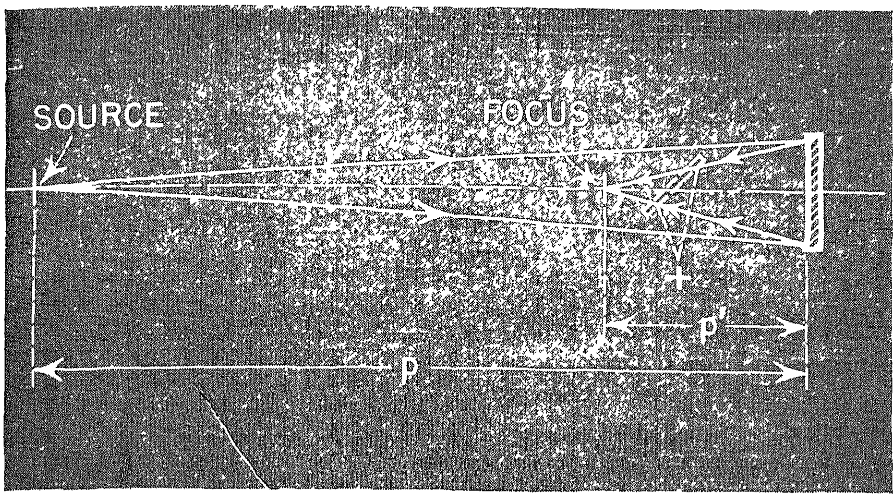
"Column 1," Wyld writes, "gives separation of primary and secondary mirrors along the axis.

"Column 2 gives the distance of final focus from the secondary

"Column 3 gives the effective focal length.

"Column 4 gives the minimum ratio of secondary mirror diameter to primary mirror diameter. (Add to D_2 a correction equal to $Sd/e.f.l.$, where d is the diameter of the field lens of the largest eyepiece to be used; this correction is usually approximately one half inch.)

"Column 5 gives minimum value of



Testing the primary

R/D_1 (for an OSC coma limit of .0025).

"Columns 6 and 7 give positions of the source and knife-edge respectively when using the Kirkham direct-focal test described in *Amateur Telescope Making*

"Column 8 gives the primary correction as a percentage of usual parabolic correction (for use in zonal testing of primary).

"A sample design for a 16-inch wyldalkirk follows:

"Take R/D_1 as 10, to be on the safe side in regard to coma.

"Take S as $.34R$, to avoid too large a value of D_2. (Since l' is less than S, a diagonal flat must be used to divert the image to the side of the tube.)

"R is 10 × 16, or 160, inches radius.

"S is .34 × 160, or 54.4 inches separation.

"l' is .2353 × 160, or 37.65 inches from the secondary.

"Minimum diameter of secondary is .32 × 16, or 5.12 inches.

"Correction to be added to this is .2353/.7353, or .32 inch per inch of eyepiece field-lens diameter. Taking the latter as one inch, D_2 may be made 5½ inches.

"The total effective focal length is .7353 × 160, or 117.6 inches.

"The over-all focal ratio is 117.6/16, or f7.35.

"The diagonal flat should be set forward of the secondary focal point by a little over half the tube diameter—say 10 inches in the present example. This places its center about 27.7 inches back of the secondary. The size of the flat is best determined by a graphical layout of the rays, to scale. In the present case it will be about 2.3 by 3.3 inches, assuming a one-inch eyepiece field lens

"If the Kirkham direct focal test is used to test the figuring of the ellipsoidal primary, the pinhole or slit should be set 6 378 × 160, or 1,020 inches (85 feet). The knife-edge or Ronchi grating should be set .5425 × 160, or 86.8 inches from the mirror, or a corresponding 'dog-leg' ray path by way of the diagonal flat used for diverting the beam. If the primary is tested by zonal tests at the center of curvature, the knife-edge motion between center and marginal zones (for a fixed pinhole) is .71 × 8²/160, or .28 inch. Similarly, the knife-edge motion for the 50 per cent zone is .71 × 4²/160, or .07 inch, and so on.

"A 16-inch mirror could be ground to size using the 5½-inch secondary blank and a larger (10- or 12-inch) grinding and smoothing tool. These tools would be used alternately, to maintain good contact.

"The primary and secondary must be polished on separate laps. The primary is brought to accurate spherical figure first. Then the secondary is tested against it by interference and brought to a sphere. Finally the primary is brought to an ellipsoidal figure by the Kirkham test or zonal testing."

Who will pioneer the first wyldalkirk?

1	2	3	4	5	6	7	8
S	l'	c.f.l.	Min.D_2/D_1	Min.R/D_1	p	p'	
.28	.3929	.8929	.44	8.00	3.666	.5790	53
.29	.3621	.8621	.42	8.15	3 970	.5721	56
.30	.3333	.8333	.40	8.30	4.318	.5655	59
.31	.3064	.8065	.38	8.45	4.718	.5593	62
.32	.2812	.7812	.36	8.59	5.184	.5534	65
.33	.2576	.7576	.34	8.72	5.731	.5478	68
.34	.2353	.7353	.32	8.84	6.378	.5425	71
.35	.2143	.7143	.30	8.97	7.152	.5376	74
.36	.1944	.6944	.28	9.10	8.090	.5329	77
.37	.1757	.6757	.26	9.23	9.252	.5286	80

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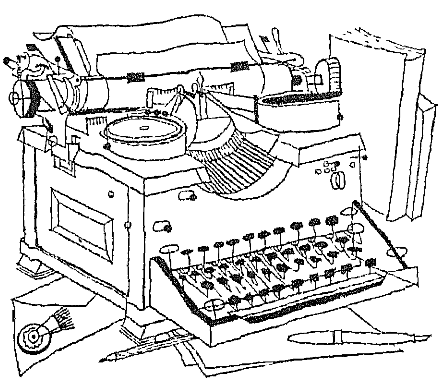
LETTERS



Sirs:

The case for national compulsory health insurance, as presented by Michael M. Davis in your June issue, is based almost entirely on the thesis that the rising costs of medical care are of growing concern to the American people and that there is a serious economic barrier between patients and doctors.

Comparing the present with the era of his boyhood, Mr. Davis reported correctly. "Medicine is now far more efficient. it saves more lives, alleviates more suffering, and has greatly prolonged the life span. But its cost is . . . higher."

It is true that the cost of medical care has increased during past decades and in the recent inflationary years. During those same periods of time, however, there also have been marked increases in the costs of all goods and services and in the income of the American people. Moreover, the cost of medical care *has risen much more slowly* in recent years than the cost of living.

According to the United States Bureau of Labor Statistics, the cost of living in 1947 was 71 per cent above the base period of 1935-1939. The same Consumer's Price Index showed that the cost of all medical care items, including hospital room rates, was only 41 per cent above the base period. Physicians' fees alone were only 36 per cent higher.

The American people, in other words, have received far gentler economic treatment from the providers of medical care than from those who dispense most other goods or services. Merely to cite an increase in the cost of medical care, without relating it to a rise in all prices and in income, does not constitute a valid argument for a nation-wide system of compulsory health insurance.

If it does, then it follows logically that the greatly increased costs of meat and milk, suits and dresses, and houses and apartments call for the use of compulsory taxation and Government control in the distribution of food, clothing and shelter. Day after day, and year after year, proper food, clothing and shelter are even more essential to life and health than are the services of physicians, dentists or hospitals.

As to the economic barrier between patients and doctors, the undramatized, unvarnished truth is that most Americans can afford adequate medical care—either by direct payment or through voluntary insurance—if they budget their incomes relative to necessities and luxuries.

The independent, impartial Brookings Institution, in its 1948 report on a careful study of "The Issue of Compulsory Health Insurance," said that "A relatively small proportion of the families have very high medical costs that confront them with serious financial problems." The report also pointed out: "*On the average medical care is not a big item. In most income classes it amounts roughly to between 4.0 and 4.5 per cent* . . . . In both 1935-36 and 1941 the available figures show for all income classes with total incomes of $1,500 a year or over that savings exceeded expenditures for medical care."

Among its conclusions and recommendations, all of which were unfavorable to compulsory health insurance, the Brookings Institution reported:

"*The large majority of American families have the resources to pay for adequate medical care if they elect to give it a high priority among the several objects of expenditure.* The issue is not whether they can afford medical care but whether they should be compelled by law to pool their risks to give payment for medical care a top priority."

The above conclusion is borne out and well illustrated by the United States Department of Commerce statistics on consumer expenditures in 1947. The American people in that year spent a total of $6.5 billion for medical care, including physicians' services, hospitals, drugs and sundries, dentists' services, and all other medical care. At the same time they spent $9.6 billion for alcoholic beverages, $9.4 billion for recreation, $3.9 billion for tobacco, $2.3 billion for personal care (toilet articles, beauty parlors, etc.) and $1.5 billion for jewelry.

In other words, the American people chose to spend one and a half times as much for alcoholic beverages as for medical care and another one and a half times as much for recreation. They decided that they could afford more than twice as much for tobacco as for the services of physicians. They spent considerably more on personal care than on care received from physicians.

These were not the decisions of the medical profession, of any other group offering medical and allied services, or of any Government bureau. They were the decisions of 147 million people, acting freely and without compulsion. The American people spent only 4 per cent of their budget on medical care, not because they were unable to spend more, but because that is all they chose to spend. That 4 per cent ratio has held true, with only slight variations, in every year since 1929.

The economic facts demonstrate clearly that the vast majority of Americans are financially able to budget medical costs. The element of free choice is involved in all consumer expenditures. The logical objective at this point is to convince the people that the costs of medical care can and should be budgeted—in a prepaid, methodical manner and at a low cost. The physical and financial health of the nation does not justify a compulsory tax for one particular service.

At the bottom of the economic ladder there are some individuals and families who are unable to pay for adequate medical care. They also are unable to provide for other necessities of life. In the future, as in the past, their medical care must be supplied through public funds or private philanthropy. Their unfortunate status is a special economic and social problem completely unrelated to the case for or against compulsory health insurance.

Mr. Davis wrote in his article that "the basic facts about medical economics in the U. S. were firmly established in a five-year study between 1927 and 1932

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by the Committee on the Costs of Medical Care, which was headed by Dr. Ray Lyman Wilbur and supported by eight large foundations." The Committee, Mr. Davis continued, concluded that future medical service in this country should be based on pooled risks, chiefly through voluntary health insurance.

That is exactly the progressive, evolutionary development which is now moving ahead at a gratifying, constantly accelerated pace, with the approval and support of the medical profession.

According to the most recent figures which have come to my attention—a survey for 1948 by the Life Insurance Association of America—voluntary insurance now covers 61 million Americans for the cost of hospitalization, 34 million for surgical benefits, 13 million for medical care, and 33 million for loss of time in the event of sickness or accident.

The figures are increasing by the thousands daily. The Blue Shield medical plans alone, for example, grew by some three million new members in 1948. The combination of Blue Cross hospital and Blue Shield medical coverage, which at last report protected more than 35 million people, is enrolling new members at the rate of some 10,000 per day.

Blue Cross, Blue Shield, the insurance companies and the various other sound private agencies in the health insurance field are working constantly to extend benefits, to provide individual coverage more broadly and to set up protection against catastrophic illness at actuarially sound rates. This healthy competition means maximum coverage for the American people at minimum rates—on a sound insurance basis rather than on a basis of compulsory taxation and Government regulation.

The cost of voluntary health insurance already is low and well within the financial reach of most American individuals and families. In the opinion of experienced administrators of voluntary programs, 75 per cent of the national population can be provided with sound, adequate coverage within the near future, if current progress is allowed to continue without Government interference. Blue Cross hospital plans, as an example of what can be achieved, already are protecting 75 per cent of the people in at least one state and in some cities.

In view of all these highly promising developments under our present medical and economic system, we agree completely with the closing statement in Mr. Davis' article: to the effect that all thoughtful men must keep cool minds to weigh the issues in this question of compulsory versus voluntary health insurance.

ELMER L. HENDERSON, M.D.

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GENERAL ELECTRIC

50 AND 100 YEARS AGO

SEPTEMBER 1899 "Chemists admit that the nature of valence is one of their chief puzzles, and they have advanced but little toward its solution during the past half century. For a long time there was much straining to consider the valence of an element always the same, but this effort is, in large measure, abandoned now as unavailing, and chemists admit that valence is not constant but variable, and may even vary toward one and the same element. This line of reasoning has led Lothar Meyer to doubt the unvarying nature of the atom itself. The case cannot be so hopeless as to necessitate calling to our aid so dangerous a doctrine."

"The role played by the mosquito as a carrying agent of the malarial parasite from man to man seems to be restricted to one genus, the Anopheles. Major Ross, of the Liverpool School of Tropical Diseases, in a telegram from Sierra Leone, announces the fact that he had found the Anopheles there, and that it may be the intermediary host of the quartan malarial fever"

"The recent war has imposed upon the United States responsibilities that are entirely novel and of far-reaching consequence. The battle of Manila sounded the death knell of our policy of isolation, and the treaty of Paris so greatly extended the borders of our possessions that they may now be said to be conterminous with those of every nation that has a fighting ship afloat upon the high seas."

"According to *The Chemical News*, Prof. Dewar has succeeded in solidifying hydrogen into a glassy, transparent mass."

"There are now over 7,000 owners of automobiles in Europe, and the number of vehicles is, perhaps, 10,000, and of this number, there are no fewer than 5,606 in France. For the remainder of Europe the figures are not very complete. There are 268 owners of automobiles in Germany, 90 in Austro-Hungary, 90 in Belgium, 44 in Spain, 304 in Great Britain, 111 in Italy, 68 in Holland, 114 in Switzerland. It is impossible to state at the present time how many automobiles are in this country. It is estimated that the number is 500 We think that 300 or 350 would be nearer the figure. A large number of concerns are preparing to turn out carriages of all kinds in large quantities, and within two years we can number our carriages by the thousand."

"Prof. W. W. Campbell has discovered that Polaris, familiarly known as the North Star, embraces three distinct bodies: 'The recent observations of Polaris, at Lick Observatory, show that its velocity is variable. It is approaching the solar system now with a velocity of 8 kilometers per second. This will increase in two days to 14 kilometers, and in the next two days will decrease again to 8 kilometers. This cycle of change is repeated every four days. The bright Polaris, therefore, revolves about the center of gravity of itself and its invisible companion once in four days. The orbit is nearly circular and is comparable in size with the moon's orbit around the earth. Both companions of Polaris are invisible, but their presence is proved by disturbances which their attractions produce in the motion of the bright Polaris.'"

SEPTEMBER 1849. "Sir John Simpson has returned to Montreal from his annual tour of inspection through the Hudson's Bay Territories and Northwestern settlements of this Continent. We learn with regret from him that no clue had been obtained to the whereabouts, or the fate of Sir John Franklin and his gallant companions."

"Some very successful experiments have been made this year and last, in the central and northern parts of Illinois, in the cropping of wheat on new prairie lands. Near New Carthage, in 1847, Mr. A. Hamilton broke 100 acres of new prairie, finishing about the 1st of August. From this 100 acre tract he cut and secured 2,300 bushels of good wheat, losing enough, he thinks, through inability to harvest it in season, to have made the whole average 30 bushel to the acre."

"The celebrated Prof. Agassiz, remarked that Zoologists, in their investigations, have sadly neglected one side of their subject. In studying animals in general, he continued, it has been the habit to observe them only in the full-grown condition, and not to look back at their earlier stages. Precise investigations of the subject are utterly neglected. But there is one point which has been most thoroughly investigated, for a period of twenty-five years, viz . the early changes within the egg. We find that young animals, of almost all classes, within the egg, differ widely from what they are in their full-grown condition. We find, too, that the young bat, or bird, or the young serpent, in certain periods of their growth, resemble one another so much that he would defy any one to tell one from the other—or distinguish between a bat and a snake, or a robin and a bat."

"Prof. Peirce observed that there had been a century of accurate observations upon the phenomena of Comets, so that the inquiry may now well come up, whether they are component parts of the Solar System, or strangers visiting us from other systems. His own opinion was that they are component parts of our own system. He came to this conclusion strengthened by two classes of arguments—the first arising from the nature of their orbits, from their not being hyperbolic."

"The growth of American cities is unparalleled in the history of the world. Already half a million are embraced within the limits and suburbs of New York; and nearly four hundred thousand in that of Philadelphia. The second child born in Cincinnati, it is said, is still living, and has not reached the middle age of life. The city has a population of more than one hundred thousand. Chicago, a place scarcely known on the latest maps, has already reached a population of eighteen thousand; and Milwaukie, of still more recent origin, is rivaling it in its growth and population."

"Mr. Penington, the original projector of a flying machine to navigate the air, which has been noticed by us before, has returned from the far west, where he has been making some experiments on the great prairies. The Baltimore *Sun* regrets to say that he has not been sufficiently successful to enable him to come back in his own carriage. He is, however, sanguine of fully succeeding eventually in making a voyage to California, or even to Europe, in his car, through the air. A large machine of this kind is now building near this city, by Mr. Robjohn. The canvas is all ready, and is about 80 yards in length and 50 in diameter. We await in calm contemplation the mighty results of this enterprise."

THE COVER

The painting on the cover shows some of the organisms used in the work of the Marine Biological Laboratory in Woods Hole, Mass. (*page 13*). Their dimensions can be judged by the three-inch watch glass in the left foreground, which holds a sharp-spined sea urchin. Behind it on the pitted wooden sink is one of the standard glass tanks used in all of the MBL's 85 separate laboratories. Sea water runs through the tank to sustain the marine organisms kept there. The speckled, green-eyed creature extending out of the picture to the right is a Woods Hole squid, *Loligo pealii* Possessing the largest known nerve fibers, with single cells two to three inches long and close to a millimeter thick, it is used in study of the nervous system. Two more squids can be distinguished in the background. Resting on the bottom of the tank is a sea anemone with reddish stinging tentacles. To its left is some living coral. Another piece of coral sits on the sink in front of the tank at the far right.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
13-17	K. Chester
19	Eric Mose
20-21	F. B. Bang and G. O. Gey, The Johns Hopkins University Medical School
23	K. Chester
24	Julius Spector
34	K. Chester
36	William Auerbach-Levy
37	National Bureau of Standards (*top*), K. Chester (*bottom*)
38-39	Eric Mose
40-41	Mount Wilson Observatory
42-43	National Film Board of Canada
45-47	David Stone Martin
49-50	James Lewicki
51	David E. Green
53	F. W. Went
56	Kurt Safranski
62	Lyle T. Johnson (*left*), Joseph F. Odenbach (*right*)
63	Joseph F. Odenbach

SCIENTIFIC AMERICAN

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CONTENTS FOR SEPTEMBER 1949 VOLUME 181, NUMBER 3

ARTICLES

DEPARTMENTS

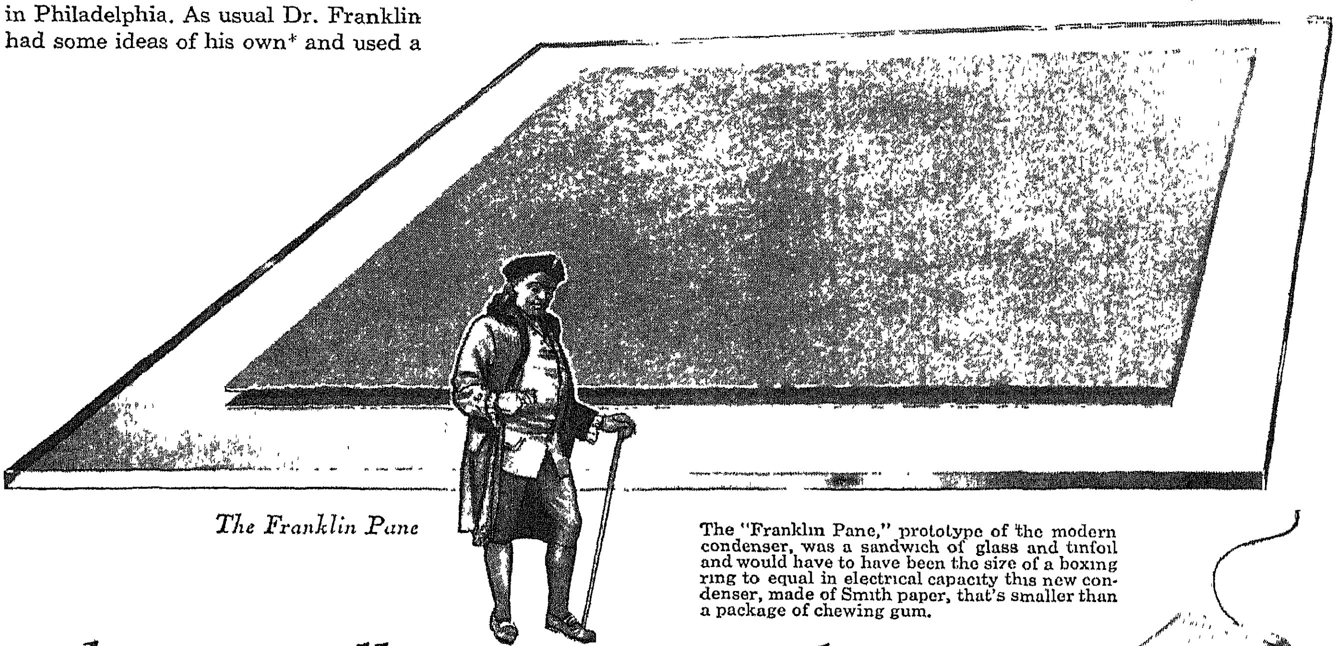
The Leyden Jar

Between 1745 and 1750 divers Europeans were experimenting excitedly with The Leyden Jar. Dr. Priestly declared its discovery to be "the most surprising yet made in the whole business of electricity."

Early in 1747 Peter Collinson, fellow of the Royal Society, sent an "electrical tube" to his friend, Benjamin Franklin, in Philadelphia. As usual Dr. Franklin had some ideas of his own* and used a Leyden Jar in his famous lightning-kite experiment. It was Franklin who identified the principle and improved on the jar with the simple "Franklin Pane," a piece of glass with tinfoil on each side. Today's condensers are practically piles of Franklin Panes.

*Puckish old Ben even made a "magic portrait" of the King out of metal on glass with a removable crown. When an uninstructed person attempted to remove the crown he received a "tremendous shock" This served as a warning for too ardent patriots.

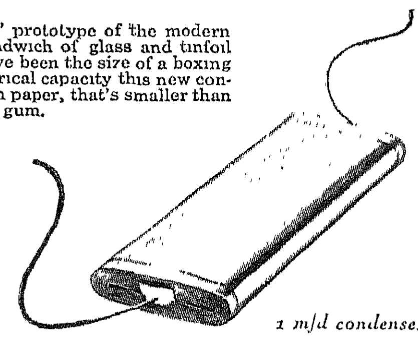
That's better Dr. Franklin, but–



The Franklin Pane

The "Franklin Pane," prototype of the modern condenser, was a sandwich of glass and tinfoil and would have to have been the size of a boxing ring to equal in electrical capacity this new condenser, made of Smith paper, that's smaller than a package of chewing gum.

–this one will go in your pocket



1 mfd condenser
Actual size

It was Franklin who took the first step toward the modern condenser. The most recent step in its improvement has been taken by Smith Paper, Inc. of Lee, Mass.

Smith has been making very thin papers for years — papers as thin as .00025 in. With the growth of electronics Smith's condenser paper became a product of considerable industrial importance.

An ordinary condenser is a roll of many alternate layers of conducting metal and non-conducting paper each of which, for compactness, should be as thin as possible. But there are limits to their thinness for should a momentary overload break through the insulator the condenser is short circuited and ruined.

Now, with the help of National Research, Smith has found a way to greatly reduce the size of condensers and prevent most shorts at the same time. In our continuous coating machines Smith evaporates metal under high vacuum. The metallic vapor, deposited on a moving strip of lacquered paper, forms a conducting film only 3 to 5 millionths of an inch in thickness. This is only 1/50 of the thickness of the foil formerly used. This metal-coated paper is also self-healing. If a momentary excess of voltage should puncture the paper the zinc coating vaporizes and recedes from the edge of the hole where it can make no contact with the next conducting layer. Extra layers of paper for insulation insurance are no longer necessary.

So, with 1/50 of the conductor and a half (or less) of the insulator the new Smith paper saves about 75% in the bulk of the finished condenser. Such a decrease in size and increased life expectancy are great advantages to all makers of television and other electronic equipment.

Isn't it cheaper to make a better product than to promote an ordinary one? We at National Research believe, by the evidence of our own experience, that it is. And we also believe that in the unexploited uses of industrial research lie the greatest opportunities for profit now offered to industry. To industry — to *your* business — we can bring the best in brains, organization and equipment with an unequalled accumulation of experience.

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SCIENTIFIC AMERICAN

SEPTEMBER 1949 VOL. 181, NO. 3

WOODS HOLE IN 1949

The Cape Cod resort is the summer capital of biology. This year, as usual, the pleasant ferment of the Marine Biological Laboratory has produced some noteworthy work

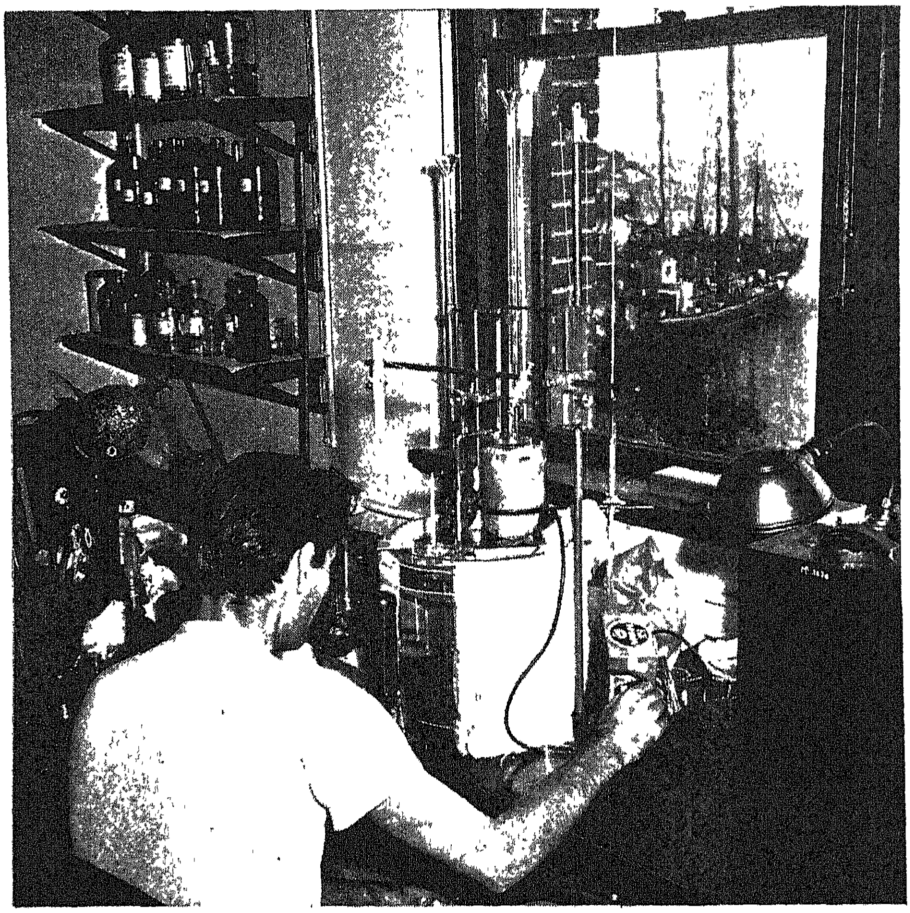
by John E. Pfeiffer

IN the summer of 1871 the renowned naturalist Spencer Fullerton Baird, then head of the U. S. Fish Commission and later to be secretary of the Smithsonian Institution, scouted the Atlantic coast from Maine to Maryland in search of a suitable site for a Bureau of Fisheries station. He arrived one day at a quiet little village called Woods Holl, on the southernmost tip of Cape Cod, and knew at once that he need look no farther. The rocky pools, mud flats, lagoons and bays of the area teemed with a rich variety of marine life. The site was ideal for fish studies.

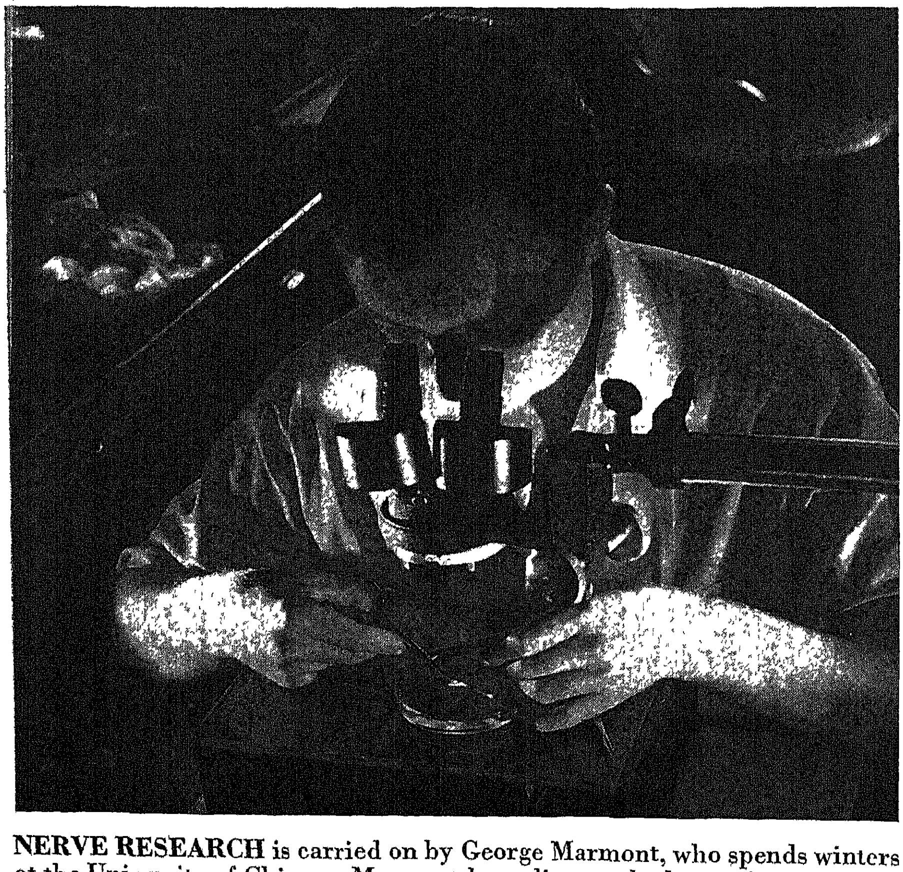
Baird's discovery not only launched a fisheries station (still in existence) at Woods Holl, but soon attracted the attention of biologists. In 1887 a group of them, led by Alpheus Hyatt, curator of the Boston Society of Natural History, decided to start a biological laboratory there. Having raised $11,000 through contributions, the proceeds of a series of popular-science lectures and an operetta written and produced in Boston especially for the benefit of the laboratory, 15 pioneers founded the Marine Biological Laboratory in a small frame building in Woods Holl in the summer of 1888.

Two previous attempts to establish a permanent biological station in the U. S., inspired by Harvard's great naturalist Louis Agassiz, had failed. But the Woods Holl seedling took root. Watered by large gifts from Charles Crane, the Chicago plumbing equipment manufacturer, the Laboratory steadily expanded.

A WOODS HOLE CLASSROOM is photographed through an unfinished wall. Here students are permitted to deliver papers. Pointing to the blackboard is E. S. Guzman Barron, head of the physiology department.



MUSCLE RESEARCH is conducted in the laboratory of Nobel prize winner Albert Szent-Gyorgyi [SCIENTIFIC AMERICAN, June]. Here a Szent-Gyorgyi associate observes the contraction of the isolated *musculus psoas* of a rabbit.



NERVE RESEARCH is carried on by George Marmont, who spends winters at the University of Chicago. Marmont here dissects the largest known nerve cell from the nerve tissue of a squid (*see photograph on opposite page*).

The plant has now grown to more than 25 buildings, including living quarters for hundreds of workers. The Laboratory has an endowment of nearly $1 million, provided by Crane, the Rockefeller and Carnegie Foundations and John D. Rockefeller, Jr., but its activities are so extensive that, like a university, it requires contributions to meet expenses. The village of Woods Hole (its present name is a corruption of the original) today can fairly be considered the biological capital of the world.

This summer more than 450 investigators and students from about 100 universities, medical schools and government agencies have put in a full season's work at the Laboratory. Some 200 others have come for shorter periods from all parts of the earth—India, Austria, England, South Africa, China, Japan. Six Nobel prize winners have been in attendance, and the Laboratory's battered registration book is a roster of great names. The 200 research projects that have been conducted at Woods Hole this summer cover almost the whole spectrum of biology.

Woods Hole is an ideal natural site for biological work for a number of reasons. The ocean is a museum of living links with the past. While land life has been vastly altered by geological upsets, the forms of sea life have remained relatively unscathed: *Limulus*, the modern horseshoe crab, is not too distant a cousin of the trilobites that crawled in Paleozoic muds half a billion years ago. Woods Hole is strategically located at a crossroads of marine life. Its waters have, to begin with, a great variety of their own native forms. From the Gulf Stream, only about 150 miles offshore, the winds often sweep in tropical marine plants and animals. And northwest, inside the great hook of Cape Cod, the waters of the bay average eight to 10 degrees cooler than at Woods Hole, adding still other varieties of life. Within the waters of the Cape Cod region, more than 1,000 species of marine organisms have been identified.

Thus Woods Hole's natural attractions have been sufficient to draw biologists from all over the world. More than 20 years ago the Hungarian muscle physiologist and Nobelist Albert Szent-Gyorgyi visited the Laboratory and was so impressed that he resolved to come back some day. He has recently bought a home in Woods Hole and set up an all-year-round laboratory, where, with a staff of colleagues who have followed him from Hungary during the past year, he is continuing his muscle studies. Other Nobelists at Woods Hole this summer have been James Franck, the University of Chicago physicist; Otto Loewi, the New York University biochemist; O. Myerhof, the University of Pennsylvania muscle physiologist; Carl Neuberg, the German biochemist, and Otto Warburg,

the German physiologist and worker in photosynthesis and cancer research.

Woods Hole is now a predominantly scientific community with well-established traditions. Some of its regulars have worked there each summer for 40 years or more. Their dean and unofficial historian, Princeton's famous Edwin Grant Conklin, who has spent his summers at the Laboratory off and on ever since 1891, estimates that at least 75 biologists have bought homes in the area, and that more than 100 marriages have resulted from summer meetings of workers or students at the Laboratory.

The Marine Biological Laboratory is not only a research center but also a vacation-term graduate school. Its carefully selected students are taught by an all-star cast; the distinguished faculty of its physiology class, for example, this summer included Szent-Gyorgyi, Warburg, Loewi, George Wald of Harvard University, H. B. Steinbach of the University of Minnesota, Hans Neurath of Duke University and E. S. G. Barron of the University of Chicago.

The Laboratory has now become so popular that it can accommodate only part of the applicants who seek to work there each summer. It has 85 individual laboratories, with space for about 375 workers. The fees for their use, usually paid by the scientists' institutions, vary from $100 to $250 for the season, depending on the size of the space. Applications are made during the winter to the director of MBL, Charles Packard, the applicant specifying what kind of work he wishes to do and what laboratory facilities he will need. If his work requires special equipment, he must bring his own, but MBL supplies such standard apparatus as microscopes, autoclaves, refrigerators, tissue-slicing microtomes—and of course the plants and animals for experiments. The demands of the biologists keep a whole corps of specimen-collectors busy. An average day's requirements include 1,000 minnows, 450 fiddler crabs, 400 sand dollars, 350 sea urchins, 250 starfish, 50 squid.

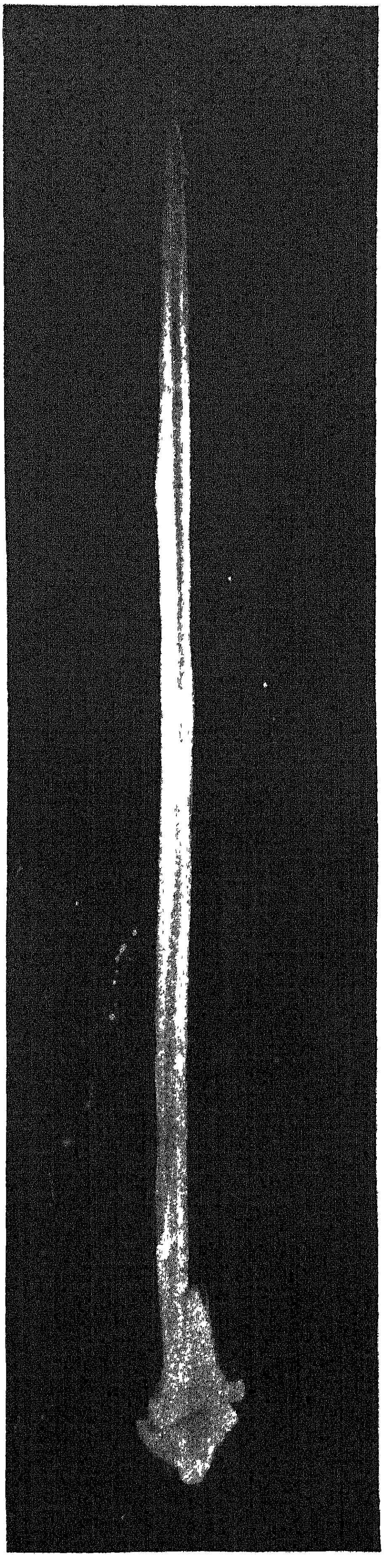
Woods Hole's unparalleled natural assets and pleasant scenery are not, however, its sole or even its major attractions for biologists. Its chief allure is as a forum and clearing house for the Babel of special tongues into which modern biology has disintegrated. In a field so fragmented that its members are divided into more than 30 specialized societies, each studying a different segment of the curious phenomenon of life, Woods Hole serves as a common meeting ground where the pieces may perhaps be fitted together. And because the need for communication is more acute in biology than in most other sciences, the opportunity provided by Woods Hole is correspondingly greater. Whereas the various workers in physics or chemistry convene only a few times a year, at Woods Hole the various breeds of biologists—zoologists, botanists, physiologists, endocrinologists, neurologists, biochemists, and so on—come together to talk things over at leisure for three and a half months.

The history of the Marine Biological Laboratory epitomizes the history of the major movements in biology during the past half century. It was the central arena for the great controversies between the vitalists and the mechanists, the analysts and the synthesists, the naturalists and the experimentalists. When the Laboratory began, biology, under the dominant influence of the naturalist Louis Agassiz, was almost wholly a descriptive science. The early workers at Woods Hole devoted themselves to observing the behavior of whole organisms; how they were born, how they lived, what they ate, how they reproduced. To tamper with the living cell or interfere with natural processes, they held, would produce misleading "artifacts." So the investigators patiently watched marine eggs under the microscope and recorded what they saw as the eggs grew, multiplied and developed.

In the 1890s a profound change began in the work of the Laboratory. The man who did most to bring it about was Jacques Loeb of the Rockefeller Institute for Medical Research. In rebellious exasperation with the naturalists' approach, he exclaimed: "The most uninteresting thing I know is the normal development of an egg!" Loeb proceeded to explore biology at the molecular level. In the face of bitter opposition from the vitalists and others, he showed that the mysterious, complicated proteins, one of the main components of protoplasm, were composed, like other forms of matter, of identifiable molecules. He also demonstrated that sea-urchin eggs could be made to develop by treatment with a salt solution instead of sperm, that the bending of plants toward the sun could be explained by chemical reactions produced in the plants by light.

Under the influence of Loeb, who worked at Woods Hole from 1892 until his death in 1924 and was buried in the town, the Laboratory—and with it all biology—gradually shifted its chief emphasis to biochemistry. Today most of its investigators are studying cells—dissecting them with microscalpels, injecting chemicals into them with microhypodermic needles, measuring their electrical activity, breaking them down in high-speed centrifuges.

One of the principal fields of investigation at Woods Hole this summer is the cells of the brain and nervous system; more than a score of workers have been engaged in it. The most popular experimental animal for this work is *Loligo pealii*, the Woods Hole squid. The squid is a good animal for nerve studies be-



SINGLE NERVE CELL of a squid is dark streak running length of bit of nerve tissue. Magnified three times.

cause it has extraordinarily large nerve fibers Fibers two to three inches long, resembling grayish-white threads, can be dissected from the animal for electrical and chemical analysis. The chemistry of nerve-cell activity is extremely complicated. A nerve cell is a kind of battery that discharges to produce an impulse and is recharged chemically in a few ten thousandths of a second for the next impulse.

Some ingenious new equipment and methods for the investigation of the nerve reactions were in evidence at Woods Hole this summer. One was a complicated apparatus, built by George Marmont of the University of Chicago, that stimulates isolated squid fibers electrically and can measure their high-speed nerve impulses with an accuracy of better than a millionth of a second. The apparatus requires about 260 vacuum tubes, and includes a platinum-wire electrode tiny enough to be inserted longitudinally in a single fiber. In another approach to the nerve problem, Otto Schmitt of the University of Minnesota spent the summer at Woods Hole studying "resting" or unstimulated squid nerve, with the aid of a small electronic computing machine to solve mathematical equations. From the chemical side, David Nachmansohn of the Columbia University College of Physicians and Surgeons, another Woods Hole regular, extracted choline acetylase from squid nerve to study the role of that enzyme in the transmission of nerve signals.

These related studies admirably illustrate the function of the Marine Biological Laboratory itself in cross-fertilizing the work of various researchers on common problems. Besides bringing the workers together, Woods Hole has given their work an invaluable continuity over the years. One of the best examples of this is the continuing study of fertilization and reproduction that has been carried on at Woods Hole ever since Loeb's experiment in the artificial fertilization of sea-urchin eggs.

What happens chemically when sperm and egg unite? In 1912 Frank R. Lillie, then director of the Laboratory, published the first of a series of papers which postulated that two substances unite to trigger the production of an embryo. One was a substance called "fertilizin" in the egg, and the other was an "antifertilizin" in the sperm. Lillie was unable to make a detailed study of these substances, for the necessary analytical techniques did not yet exist. But in recent years Albert Tyler of the California Institute of Technology has continued this investigation at Woods Hole.

Using a high-speed centrifuge and other apparatus, Tyler determined that fertilizin is a sugar-protein complex of large molecular size, found in the surface coat of the egg. Antifertilizin, extracted from the surface of the head of the sperm, was also found to be a protein. As a working hypothesis, Tyler has suggested that when a sperm encounters an egg, the specific interaction of its antifertilizin with the egg's fertilizin binds the sperm to the surface of the egg. The sperm's tail soon stops wiggling. Eventually it appears to be pulled into the egg by purely chemical forces, involving the precipitation of the two reacting substances.

This may seem merely a way of saying in chemical terms what any high-school student can observe with a microscope. But biochemical analysis, besides affording a fuller description of a given process, often reveals unsuspected common denominators that illuminate other processes in a living organism. In this case the process of fertilization turned out to be very similar to the reaction of the body to foreign substances. The combination of fertilizin with antifertilizin is like the combination of an antibody with a foreign substance, such as the germ of a disease, a poison or ragweed pollen. In other words, fertilization and allergy are somehow akin, at least in their mechanism. Even the substances are alike: fertilizin and antifertilizin, like antibodies, are proteins.

The parallel between fertilization and infection is even more striking when one examines the viruses, known as bacteriophages, that attack bacteria. Some studies have shown that after a single phage out of a large colony enters a bacterium all the others may be excluded. This is exactly what happens, of course, when an egg is fertilized; one sperm preempts the egg. Tyler has even pointed out, though he is not inclined to push the parallel too far, that under the electron microscope some phages actually look like sperm; they have short oval heads and relatively long tails.

In any case, Tyler's revealing studies of the parallels between fertilization and infection have already suggested applications to medicine. It has been found, for example, that marine sperm possesses substances that dissolve the protective layer of cells surrounding the egg. So medical scientists are testing chemicals closely related to these substances to treat human infertility, dissolve kidney stones, and enhance the effect of penicillin and local anesthetics.

Thus biochemistry appears at the moment to be the most fruitful and liveliest field in biology Easily the most dramatic event at Woods Hole this summer was a debate on the chemistry of photosynthesis among four of its investigators. Otto Warburg of Berlin, James Franck of the University of Chicago, Dean Burk of the National Cancer Institute and Robert Emerson of the University of Illinois. The debate had to do with the efficiency of the photosynthetic process. Warburg has long contended that the photosynthetic reduction of carbon dioxide requires no more than four quanta of light energy, which would mean that the efficiency of the process is 70 per cent In recent years Emerson and others have reported on the basis of tests similar to those of Warburg that the energy requirement is 10 to 12 quanta, and the efficiency is only about 20 to 30 per cent. In the debate this summer Emerson and Franck, who has supported his findings, were confronted with new evidence that reopened the question. Warburg and Burk, having conducted a new series of experiments, declared that it now appears that photosynthesis requires only three quanta of energy, meaning that its efficiency is better than 90 per cent. The debate settled nothing, but it ensured a vigorous revival of work on this problem.

Yet there were plenty of signs at Woods Hole this summer that biochemistry may have reached its crest and the center of interest in biology may soon swing to a more integrated view of the living organism. One sign was the fact that a popular topic of discussion this summer was Norbert Wiener's cybernetics, which attempts to draw an analogy between mathematical machines and the human nervous system. Biologists have long had a deep-rooted distrust of analogies. Their view is summed up in an epigram credited to the late geneticist Thomas Hunt Morgan, who once remarked acidly that scientists who compared living systems to machines were like "wild Indians who derailed trains and looked for the horse inside the locomotive." Nonetheless, cybernetics and other recent attempts to describe the functioning of the living organism as a whole in modern terms have definitely aroused the biologists' interest. Many of them believe that biology may need a new nonbiochemical approach to explain some of the baffling phenomena that biochemistry itself has revealed.

For instance, biochemists had begun to arrive at a picture of the cell as a clearly defined unit with a membrane like a sausage casing that set a limit on the size of molecules that could pass through it. But they have now found that certain large protein molecules manufactured inside the cell somehow manage to escape through the membrane, despite the fact that the "holes" in it are not nearly large enough Thus they may have to revise radically their notions about cell structure. Again, the 1,000 to 2,000 reactions in a cell, taken as a whole, add up to an intricately related system that may never be explainable in strictly biochemical terms.

Thus it may be no accident that biology shows an increasing tendency to merge with physics, mechanics and mathematics. Many a specialist from those fields has moved into Woods Hole, which each year becomes, at least in the field of science, more and more cosmopolitan.

AT 10:30 P.M. the inhabitants of the Marine Biological Laboratory are still hard at work. This photograph shows the lighted windows of the Laboratory's old main building, or "Old Main." On the upper story of the building a physiology seminar is in session. On the story below a student works in the embryology laboratory.

ENCEPHALITIS

It is not one but many diseases. Some dangerous epidemic forms of it are caused by viruses living in an intricate sequence of other organisms, including the horse and man

by William McD. Hammon

EPIDEMIC encephalitis, of which there have been several large outbreaks in various parts of the world during the past quarter century, is a hideous and terrifying disease. Misleading publicity and the resultant hysteria during epidemics have exaggerated its over-all importance as a human killer; even in the worst epidemics it affects no more than two or three persons in a thousand, and among this relatively small number the mortality is usually 5 to 25 per cent. But the disease is especially terrifying because it frequently strikes most severely among infants and often leaves fearful permanent effects—spastic paralysis, deformities, even idiocy.

Encephalitis simply means inflammation of the brain. The particular disease, or, more accurately, diseases, that we are considering are a group of virus infections transmitted by mosquitoes and mites or ticks. They infect many animals and birds. The chief sufferers are horses and man; among horses 40 to 90 per cent of those affected die or are permanently disabled. In man, encephalitis is often mistaken for poliomyelitis, for in mild infections its symptoms are almost exactly like those of mild polio. But severe encephalitis is very different. In infants its onset is generally sudden. the child refuses to nurse, is shaken with convulsions, runs a temperature of 105 to 107 degrees Fahrenheit, turns blue and develops a number of other drastic symptoms, often complicated by pneumonia. Although the child may appear to recover completely, not infrequently permanent damage to its brain becomes evident months later as it fails to develop the ability to crawl, walk or talk. Even in older children and adults the disease runs a violent course—high fever, excruciating headache, stupor merging into coma, and, if the patient survives, a long convalescence. A severe case of this disease is one of life's most unfortunate experiences. After an experience with a single case, it is easy to develop a zeal for prevention of the affliction.

Since about 1930 many scientists have devoted themselves to that effort. It is a task for epidemiology, which is the study not merely of epidemics but of the natural history or ecology of disease. An epidemiological investigation is a kind of "Who done it?" The epidemiologist's job is to discover the criminal, learn his methods, bring him to trial, and convict him, so his activities may thenceforth be restricted.

In this case we have not one culprit but several, and a number of accomplices. If our present hypotheses are correct, the encephalitic diseases of man and horses represent possibly the most complex disease cycle so far unraveled. The investigation of them has called for many experts representing numerous branches of science, all contributing important parts to the whole. Progress has not come in a regular sequence, but piecemeal here and there, as results obtained from tracking down an agent of the disease in one area have been applied to a related agent elsewhere.

EPIDEMIC waves of "horse plague," "blind staggers" or "brain fever" have struck the equine population in various parts of the U. S. since the beginning of the present century. Not until 1930, after thousands of horses were lost to one of these great epizootics in California, did Dr. Karl F. Meyer and associates at the University of California corner the first criminal. They found that the cause of the California outbreak was a filtrable virus. The disease was eventually named "Western equine encephalomyelitis." Two years later a second agent, related but different in behavior, was indicted by Dr. Carl Ten Broeck of the Rockefeller Institute as the cause of a more generally fatal horse epizootic in the eastern U. S. This form of the disease was called "Eastern equine encephalomyelitis." Since then several other members have been added to the group: St. Louis encephalitis, Venezuelan equine encephalomyelitis in South America and Panama; Japanese B encephalitis in Japan, Korea, China, other parts of the Asiatic mainland and on many Pacific islands; West Nile and Mengo diseases in Africa; spring-summer tick-borne encephalitis and autumn encephalitis in the U.S.S.R. In all probability other forms will be found.

After the California group had determined that the criminal was a virus, the next step was to find out how it was transmitted. When experiments showed that the virus was not transferred from one horse to another by contact, good epidemiologic reasoning gave rise to the suspicion that it was carried by mosquitoes Because mosquitoes of the *Aëdes aegypti* species were known to be carriers of the virus diseases yellow fever and dengue, Dr. Raymond Kelser, then a colonel in the Army Veterinary Corps, decided to investigate this species. In his laboratory he succeeded in transmitting the Western type virus from guinea pig to guinea pig, and then to horses, by means of these mosquitoes. Other workers found that another *Aëdes* species could carry the Eastern virus, and eventually many other species of *Aëdes* were implicated as possible carriers. These experiments supported, but by no means proved, the hypothesis that the infection was actually spread by mosquitoes in nature outside the laboratory.

Meanwhile Dr. Meyer, carrying out studies in the hot, mosquito-ridden San Joaquin Valley of California, started another line of investigation. Until about 1934 the encephalitis viruses were considered to be of importance only to horses. Dr. Meyer wondered whether they might also attack men. He was not convinced that all of the illness being reported as poliomyelitis was actually polio. Brain sections he examined at autopsy revealed lesions in human beings exactly like those in horses, so he stimulated efforts among his workers to find the equine virus in man.

In 1933 and 1934, epidemics of human encephalitis exploded in Paris, Ill., and in St. Louis, Mo. The latter epidemic of 1,000 cases and more than 200 deaths, occurring within a few weeks in the late summer, made daily headlines across the country and brought together one of the largest, most highly integrated teams of epidemiologists and bacteriologists, virologists and entomologists ever assembled at the site of an epidemic. The cause, discovered independently in the laboratories of two of the institutions represented, was found to be still another virus, somewhat like the equine viruses in size and in the disease it produced, but immunologically unrelated to them.

Opinion as to whether the viruses were spread by contact or by mosquitoes was sharply divided.

In 1926 Japan had had the greatest epidemic of human encephalitis on record, with over 6,000 cases. Outbreaks had continued there in the following years. As late as 1935, the infectious agent responsible for the disease had not yet been discovered. The results in St. Louis led the Japanese to try to isolate the virus responsible for their disease by the American methods. In 1937 they succeeded in identifying an agent called the Japanese type B virus. It was related to, but different from, the St. Louis virus. The Japanese soon afterward announced that they had succeeded in transmitting not only their virus but the St. Louis virus through mosquitoes. The Japanese went a step further. They found mosquitoes outside the laboratory that were infected with their virus—the first definite indication that mosquitoes were natural carriers of the disease. However, the Japanese work with the St. Louis virus could not be duplicated by American workers, and later Japanese investigators also failed to confirm the original Japanese B mosquito virus work.

In 1938 three different investigators—Beatrice Howitt of Dr. Meyer's group in California; Dr. Leroy D. Fothergill, Dr. John H. Dingle and co-workers at Harvard University; and Dr. Leslie T. Webster at the Rockefeller Institute in New York—all found "equine" viruses in the brains of human beings who had died of epidemic encephalitis. These viruses were identical with the Western strain from California and the Eastern strain from Massachusetts. From then on interest in the "equine" viruses was no longer restricted to veterinarians and entomologists. Almost overnight a horse disease became a public health problem.

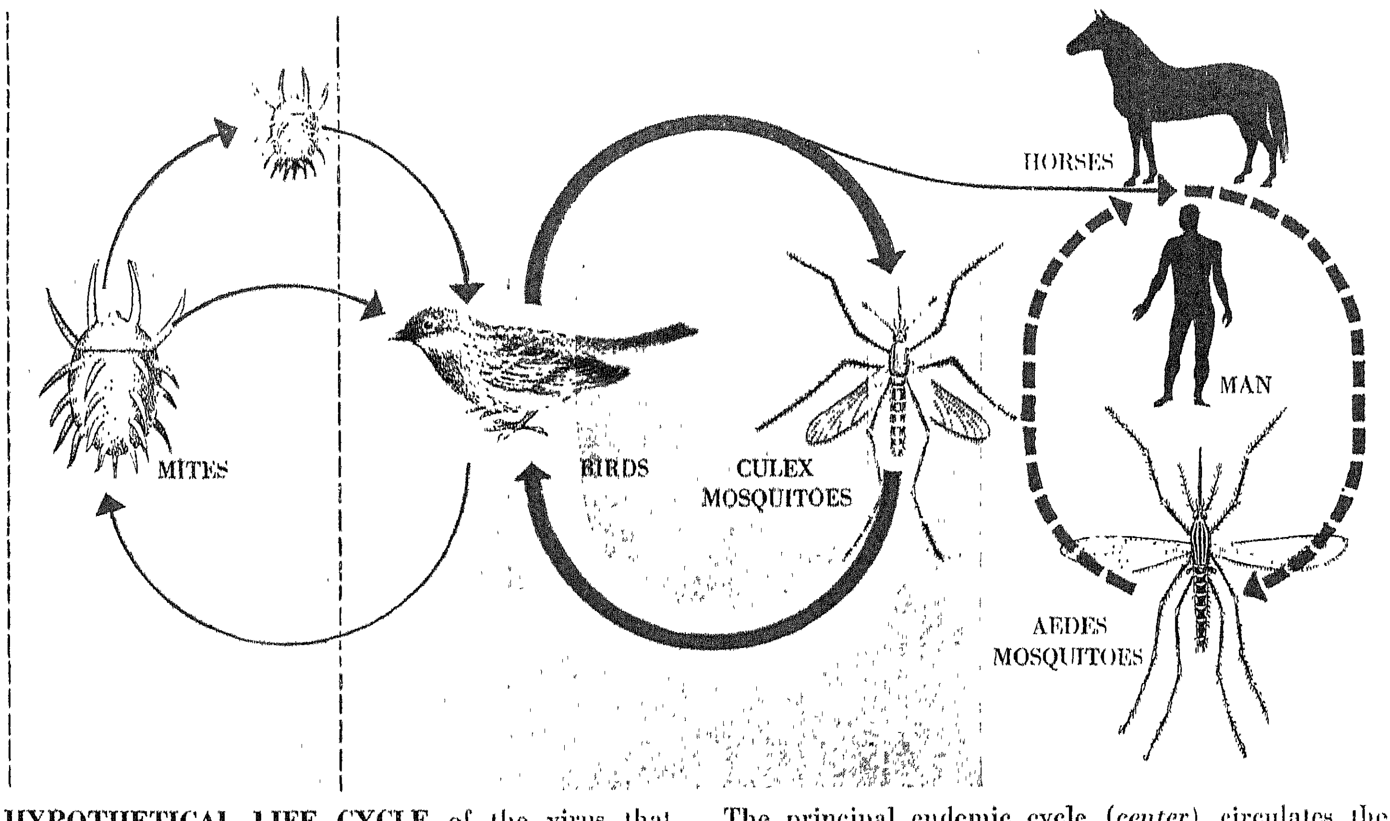
The Russians, in the meantime, isolated a viral agent causing encephalitis and paralysis in forest workers. They found it in ticks, and demonstrated that the ticks transmitted the virus by biting animals. The ticks also passed on the virus through the egg from one generation to the next. The Russian agent was reported to be related to the Japanese virus. American workers found that it was similar to, or possibly identical with, that causing a paralytic disease of sheep in Scotland. Later Russian scientists reported isolating a virus which they believed was the same as the Japanese B virus. This agent was the cause of a human disease called autumn encephalitis in the Far Eastern Maritime Provinces.

IN THE U. S. immune substances that indicated the patients had been infected with St. Louis virus were detected in the blood of encephalitis convalescents from many states. The work of two groups confirmed the Russian report that ticks could transmit some of these viruses in the laboratory, both to animals and to their own offspring. The wood tick was shown to transmit one of the equine viruses, and the brown dog tick was implicated as a laboratory vector for St. Louis virus. Then a *Triatoma* (kissing bug) caught in Kansas pastures was found to be naturally infected with the Western equine virus, adding another possible culprit to the list.

At about the same time birds also came under suspicion. During a 1938 human epidemic of encephalitis in Massachusetts, pigeons, pheasants and turkeys were found ill and dying of the disease. Dr. William Davis at Harvard infected *Aedes* mosquitoes by feeding them on birds inoculated with the virus; the infected birds transmitted the infection. In California experiments along the same line, chickens inoculated with the Western equine virus did not contract the disease, but antibodies were found in their blood. Similar antibodies were found in the blood of fowl in the endemic encephalitis areas—indicating that chickens were probably being infected by natural means.

In 1940, when it was still a question whether the "equine" viruses were transmitted by mosquitoes, ticks, kissing bugs or human contact, other fruitful studies were begun at the Hooper Foundation of the University of California.

DURING the first few years, collections and observations were made principally from a field laboratory in the Yakima Valley of Washington. Eventu



HYPOTHETICAL LIFE CYCLE of the virus that causes Western equine encephalomyelitis involves three lesser cycles. The possible reservoir of the virus (*left*) is mites, which pass it along to their young and to birds. The principal endemic cycle (*center*) circulates the virus among birds and *Culex* mosquitoes. The possible epidemic cycle (*right*) involves the infection of horses and men, who transmit virus through *Aëdes* mosquito.

ally a graduate student in medical entomology, W. C. Reeves, who became interested in this problem and made major contributions to the studies, directed a series of field laboratories in several Western states as part of our investigation. Other valuable colleagues—physicians, zoologists, bacteriologists, virologists and entomologists—joined the group for varying periods. This continually expanding group is still working on the epidemiology and methods of accurate differential diagnosis of epidemic encephalitis. Members of the unit have studied various aspects of the disease in Washington, Nebraska, Oklahoma, Idaho, Iowa, South Dakota, Texas, New Mexico, Arizona, California, Japan, Korea, China, Okinawa and Guam. The work has had support from many agencies, including the National Foundation for Infantile Paralysis, the U. S. Army, the California State Department of Public Health, the U S. Public Health Service, the California Division of Fish and Game, the Kern County Health Department, and the Kern Mosquito Abatement District.

From the Yakima Valley, thousands of mosquitoes were collected and inoculated into mice. Up to this time suspicion had pointed most strongly to the *Aëdes* species. But now St. Louis and Western equine viruses were repeatedly discovered in the previously "unimportant" and little-studied mosquito *Culex tarsalis*. *Aëdes*, *Culisata* and *Anopheles* also were eventually found to harbor viruses, but only rarely. *Culex pipiens*, previously reported as a laboratory vector by the Japanese, was tested again and found to carry the St. Louis virus. *Culex tarsalis*, however, rapidly occupied the center of attention as the most important criminal in the two diseases present on the West Coast.

Microscopic examination of the blood from hundreds of trapped wild birds and domestic fowl in the hot, irrigated valley areas of Washington and California pointed to widespread infection of many avian species with both St Louis and Western equine virus. Moreover, when birds were inoculated by "natural" routes (into the skin) with very minute amounts of either of these two viruses, the virus multiplied rapidly and could be found in the blood in large quantities for two to four days after inoculation. Mosquitoes that fed on the birds when virus was circulating in their blood picked up the virus. Later, in the laboratory, the mosquitoes infected other birds or mammals Thus it was shown that birds could serve to infect mosquitoes. But were they the chief natural reservoirs of the disease? Tests on mammals indicated that they too were implicated as hosts. When horses were inoculated with St. Louis virus, they showed a high rate of infection. They rarely revealed symptoms of any disease from this "human" virus, but the infection was present though not apparent. Thus it was possible that these large mammals were sources for the infection of mosquitoes.

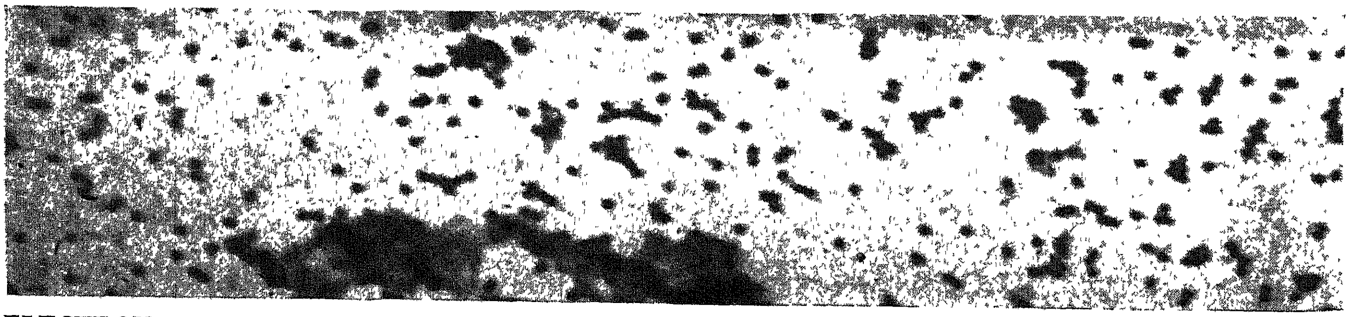
It was important to know whether infected people or horses could be sources of danger, for if they were, the disease must be attacked either by isolating them or by immunization, at least of horses, on a mass scale. Because experimental work with horses would have been much too expensive, it was necessary to look for indirect evidence as to whether large mammals could infect mosquitoes.

One indirect means was to examine the blood of human encephalitis patients. In practically all cases of Western equine and St. Louis infections, man was found free of virus in the circulating blood during the early stage of illness. This was significant, because it was known that in such virus diseases as yellow fever, dengue and sand-fly fever, virus is available in the patient's blood during the early clinical stage. But it was not conclusive, for it remained possible that in encephalitis the virus might be present in the blood *before* the onset of the clinical illness.

A series of indirect experiments helped to clarify the point. By means of direct observation and later by precipitin tests similar to those used in criminology to identify the species of animal from which a sample of blood comes, it was determined that the *Aëdes* mosquitoes of the areas studied were feeding almost entirely on large mammals, such as cows, horses and men. Yet the *Aedes* were rarely infected with the encephalitis virus. On the other hand, the *Culex tarsalis* mosquitoes, which most frequently fed on birds, were found infected more than 10 times as often. Thus it was evident that the birds were a much more likely source of the virus

The field of suspects was narrowing down Which were the guilty birds? It was first assumed that the principal culprits were domestic fowl, because of their large numbers and close proximity to men and horses. Had chickens been the chief source of infection, the whole disease cycle might have been broken by applying DDT to all chicken houses to kill mosquitoes. But a series of large field experiments cast doubt on this hypothesis. Liberal DDT spraying of chicken houses in an endemic area did not reduce infection rates in the mosquitoes or chickens. It was clear that the mosquitoes were becoming infected elsewhere, for those entering chicken houses and feeding on chickens probably would not survive long enough for the growth of virus necessary before they could become infectious.

Consequently, strong suspicion fell on wild birds They could not be proved guilty by blood tests, for the precipitin technique, though adequate for identifying a mammalian species, does not satisfactorily distinguish one bird species from another, since all bird serum proteins are closely related. To find out whether *Culex tarsalis* mosquitoes fed on wild birds to an important degree, the investigation turned to another mosquito-borne disease—bird malaria. Bird malaria had not previously been found in this area. A search for it was made, and fortunately it was readily located, not in domestic fowl but in wild birds. Almost 100 per cent of the small wild birds examined harbored the parasites; some of the baby birds had even had malaria before they left the nest. And systematic dissection of mosquitoes showed that *Culex tarsalis* was one of the principal carriers of malarial parasites. This proved that *C. tarsalis* was feeding frequently on wild birds. Meanwhile house finches and English sparrows were inoculated with encephalitis virus in the laboratory, and it was demonstrated that more virus circulated in their blood than in the blood of similarly inoculated chickens. So the net of evidence was now strong.



ELECTRON MICROGRAPH by F. B. Bang and G. O. Gey of the Johns Hopkins University Medical School reveals virus causing Eastern equine encephalomyelitis. Original micrograph magnified virus 15,734 diameters.

plainly it was the wild birds that were chiefly responsible for supplying mosquitoes with the virus of encephalitis in the endemic areas studied. Domestic fowl were implicated only in a minor way, and large mammals hardly at all.

A KEY question had still to be answered. How and where did the virus survive during the winter? *Culex tarsalis* does not survive the winter in the adult stage in northern sections, and no encephalitis virus was found in mosquitoes wintering in the mild southern areas. The virus probably did not live through the winter in mosquito eggs, for it proved impossible to transmit the virus through mosquito eggs in the laboratory. Nor, apparently, did vertebrate animals provide it with a winter home, no latent or chronic infection could be produced with encephalitis virus in such animals.

One possible clue was the fact, noted earlier, that wood and dog ticks can transmit the virus to their offspring. But ticks could not be implicated as hosts in the areas where our work was done, large numbers of chicken ticks, among others, were tested, with negative results. Another potential host was mites, which are known to transmit the rickettsia of scrub typhus to their offspring. So large numbers of chicken mites from the Yakima Valley were studied, but here again no virus could be detected

Then Dr. Margaret Smith and her co-workers at Washington University Medical School discovered chicken mites in St. Louis that were infected with St. Louis virus. Later Dr. S. Edward Sulkin of Southwestern Medical College isolated the Western equine virus from these mites in Texas. Dr. Smith demonstrated that this mite transmitted the virus to its young and could transmit it to chickens.

We now have a fairly complete picture of the probable chief criminals, their habits and the cycle of the crime. In at least one disease, St. Louis encephalitis, evidence indicates that the true reservoirs are tiny, almost invisible mite parasites of birds, which do not bite any mammal. These mites may pass the infection along through their eggs to their progeny, without the necessity of any intermediate vertebrate host. After an infected mite bites a bird, virus appears in the bird's blood a few days later, and the bird serves in turn to infect certain types of marauding mosquitoes. In the mosquitoes the virus multiplies within the body and eventually invades the salivary glands, where it rests almost indefinitely, ready to pass on to another vertebrate when the mosquito bites.

Up to this point, none of the hosts—mite, bird or mosquito—has become noticeably ill The parasite, though multiplying millions of times and invading many of the hosts' cells, appears to be entirely harmless to them. However, should the mosquito select as its next host a horse or a human being, a very severe and possibly fatal disease may occur. In so far as the essential biological cycle is concerned, these large mammals are merely accidental hosts. they do not ordinarily pass the virus on to mosquitoes nor to others of their own species through direct contact. But they are the vulnerable victims of the disease.

WHAT are the expectations for control of the crime? If mites are finally convicted as the sole winter home for the virus and if wild bird mites are definitely involved, the possibility of breaking the chain by attacking the mites does not hold much hope. Even should an area be freed of mites, the mosquitoes might acquire the virus from migrating birds infected one to four days before in a more southern or northern climate

Horses may be satisfactorily vaccinated against the "equine" viruses by annual injections. This vaccine, however, though used on a small scale for the protection of laboratory workers, has not so far been recommended for the annual mass immunization of man. Extensive epidemics in man have been relatively rare, and they are unpredictable. The cost and effort of mass human immunization does not seem warranted as a public health measure, in view of what an equal expenditure of time and funds might accomplish in preventing other diseases.

In the better-known endemic areas of California, mosquito control, aimed particularly at *C tarsalis,* has made encouraging progress in the past three years. The local tax-supported programs have been assisted by a subsidy of over $1 million by the State of California. Human, horse, chicken and mosquito infection rates have fallen steadily. In Kern County, which in the past has had scores of cases of human encephalitis in a single year, there were 15 cases in 1946, eight in 1947 and *only* one last year. In one urban area where mosquito control has been maintained at the highest level, very little avian malaria and no encephalitis was found last year.

To attribute these gains definitely to mosquito control would be premature, for epidemic and endemic areas may remain relatively free of disease over a period of a few years for completely unknown reasons. Japan, for example, suffered no epidemics throughout the war years, and then had its worst outbreak in 1948, when attempts at mosquito control, though terribly incomplete and ineffective, were at a relatively high level as compared with previous years. Continued watching will be essential before mosquito abatement can be proved to be a sound method of control.

In other portions of the U. S., much less is known about the vectors. Until they are identified, control cannot be so intelligently carried out. Results of our cursory surveys in the Midwest and Southwest areas and of observations by others suggest at least that the essential intermediate infected vertebrate hosts and the vectors and reservoir arthropods may be quite different from those of the hot, irrigated valley areas of the Pacific Coast states where most of our studies have been made.

The teams of investigators probably have years of work before them before this group of epidemic diseases can come under rational control measures, even in the U. S. It is reasonable to expect, however, that their complex disease cycle may eventually be adequately understood in enough areas to make possible effective and relatively inexpensive control measures

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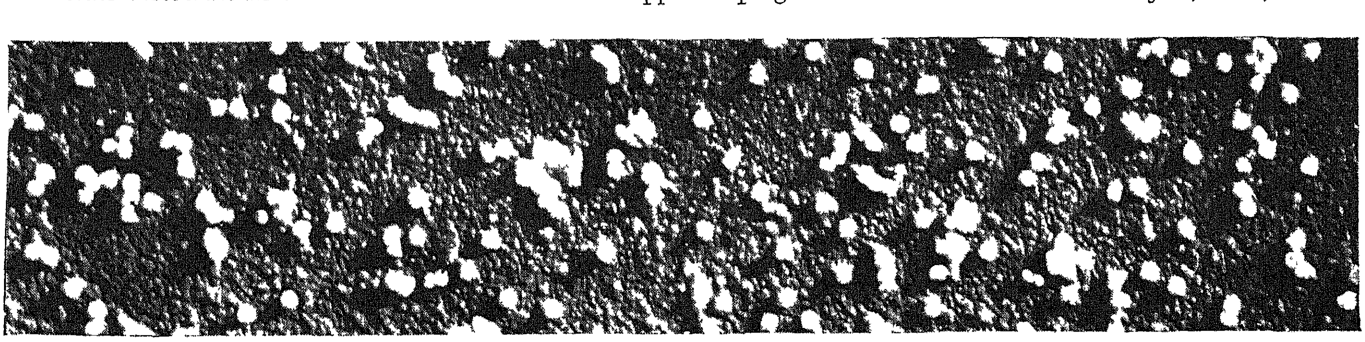


CHROMIUM-SHADOWED preparation of the slide on the opposite page shows pairs and clumps of viruses suggesting that they reproduce by binary fission. Original micrograph magnified virus 10,300 diameters.

INFANT SPEECH

The meaningless cries of babies fall into some remarkably meaningful patterns, the study of which shows differences among girls and boys and children of various environments

by Orvis C. Irwin

HOW does an infant learn to talk? With what phonetic equipment does a newborn baby come into the world? How is the baby's I.Q. related to his speech? Are there laws of speech development? These are questions of perennial interest to parents, and they pose fascinating problems to the investigator of human development.

There are two aspects to the question of the beginnings of human speech. The first deals with the origins of language in prehistoric times; the second concerns the beginnings of speech, starting with the birth cry, in the young child. The first aspect is so shrouded in the dimness of antiquity that at present there seems no hope of achieving a satisfactory solution. The second aspect, that of the origin and development of speech and language in childhood, obviously is open to observation.

For the scientific investigation of speech, the first need is a set of accurate symbols for the basic speech sounds, just as in physics and chemistry scientific progress depended upon the invention of the periodic table with precisely defined symbols for the elements. The English alphabet is not a precise scientific instrument, for one of its symbols may stand for several different sounds, and, contrariwise, different combinations of letters may represent the same sound. For example, in the words father, sergeant and hearth the symbols a, e and ea, respectively, all are sounded in the same way, like the a in ah

In the International Phonetic Alphabet, invented about 40 years ago, the speech investigator has a precise tool that makes scientific work possible. This alphabet, unlike conventional ones, has one, and only one, symbol for each elemental sound. Thus the sound ah is always represented by the symbol a. The complete alphabet is given in the table on the opposite page. In our studies at the Iowa Child Welfare Research Station these symbols were used to record the first sounds, babblings and developing speech of our infant subjects.

A second necessary tool in this work is a manageable unit of observation. This was furnished by what is known as the respiratory unit. When an individual speaks, his sounds and words are uttered on the exhalation phase of breathing. It is abnormal to speak while inhaling. Thus a baby always vocalizes while it breathes out. The breath unit readily lends itself to observation In the case of an infant, the number of sounds carried on a single breath varies from one to about half a dozen. And this number of sounds is ordinarily well within the attention span of even an untrained observer.

These two experimental tools, the International Phonetic Alphabet and the breath unit of observation, have proved invaluable for collecting reliable data on the beginnings and the acquisition of speech. They have permitted systematic observation and statistical treatment of the results.

A question frequently asked about our investigation is, "Where do you get your babies?" Obviously this is the simplest aspect of the whole endeavor, for there are plenty of babies in the world. However, the question does lead directly to the general problem of sampling the population of babies. One good source of subjects is a nursery connected with the obstetrical department of a hospital, and a great deal of our work has been done in this situation.

The home is another natural laboratory for this work. After a baby is taken home from the hospital, it is visited at regular intervals of two weeks or a month throughout infancy. At each visit a sample of the baby's speech, as uttered on a number of breaths, is written down in the International Alphabet. If care is taken to select homes of different socio-economic status, the speech sound samples may reflect a number of variables operating in the home situation, and the data subsequently may be analyzed in terms of these variables.

We have studied infants' speech development in several other situations. in orphanages, where retardation in speech is notoriously frequent; in state institutions for the feeble-minded; in schools for the deaf, where the investigation of how children deaf from birth achieve intelligible speech makes a valuable comparison with the development of speech in the normal infant.

THE earliest sounds made by a newborn babe are monosyllabic cries. During the first few days of life the infant most frequently gives voice to eight distinguishable sounds, which represent about a fifth of the sound elements used by adults. These eight include only five of about a dozen vowel sounds listed in the International Phonetic Alphabet, and three consonants of a possible two dozen. Its most frequent cry by far is æ, like the vowel in the word fat; this sound amounts to 90 per cent of an infant's vowel utterances. In one study involving 40 babies under 10 days of age, it was found to be the only vowel used by all the subjects. The other four early vowel sounds are ɪ as in fit, ɛ as in set, ʌ as in up and u as in food. The three consonants are h, l and the glottal stop, a consonant formed by pressure of the breath behind the closed glottis.

Vowels are usually classified into three groups. front, middle, and back, corresponding to the parts of the mouth and tongue used in their phonation The sound ɪ, as in fit, is a front vowel. The sound u, as in food, is a back vowel. An infant's vowel repertoire consists mostly of front vowels. In its consonant equipment the opposite is usually true: two of the three consonants it uses are phonated by the back mouth parts, namely h and the glottal stop.

As the infant grows older, non-crying sounds begin to dominate the cries. The soft cooings and utterances that delight parents become more frequent. The child achieves increasing control of the mouth parts for vocalizing back vowels and front consonants—the labials, dentals and postdentals. Then begins a long period of meaningless babbling. Babbling has a real function in speech development; it is a practice period for control of the sound elements of language. The baby seems to be trying out new vowel and consonant combinations in a bewildering array. He repeats these

sounds over and over again on varying pitches, with varying intensities and cadences. He mouths them, gets the kinesthetic feel of them with lips, tongue and cheeks, and unconsciously and endlessly practices them. Significantly, after a year of this, meaningful words—at first mere approximations of words—begin to appear upon the background of infantile babbling.

Meaningful words appear toward the end of the first year or the beginning of the second year of life. At first they constitute a very small proportion of the infant's vocalization, but during the later part of the second year they become prominent. A word usually passes through an interesting transformation. At first it is a crude approximation. In nurseries the world over, the baby lies in a crib and babbles meaningless sounds such as "mamama" or "adadada." Under the coaching of parents, these babblings are abbreviated to "mama" and to "daddy." This is the way one child learned the word milk. at first it was "meme," then "mik mik" and finally milk. Pillow is often pronounced "pido." In the case of another child, the more difficult word please evolved from "be" through the series "ble," "pez," "pwez" to please. Sometimes the first words exhibit an onomatopoeic character. Thus a watch is a "tick tick"; a dog a "bow wow"; and a cow a "moo moo."

THERE are no fundamental group differences in the inherent phonetic equipment of human beings. In the first 10 days of life, boys and girls, white children and Negroes make pretty much the same sounds. But by the time they begin to form word patterns, some sex differences do appear. For instance, at a year and a half, girls exceed boys in the ability to use consonants at the beginning, in the middle and at the end of a word. The mean number of consonants used by girls in the initial position is 8.7 as against 7.7 for boys. For the medial position, the mean for girls is 7.9 and for boys 6.9. In the final position, girls use 2.9 consonants while boys use 2.4.

The average eight-month-old child is unable to use words. At 10 months he probably will have one word; at 12 months, about three words. At a year and a half, his vocabulary may be 20 words. During the next three months it will jump to over 100, and at two years it may contain as many as 250 words.

The ultimate language problem for the growing child is to relate words into meaningful sentences. His first sentence may be a single word; for instance, he will use the word "do" to obtain many of his demands. From a single word grows a variety of longer sentences. The average child's first sentence appears soon after the 15th month. At two years the average length of his sentences is 1.7 words. At five it has expanded to 4.6

IPA SYMBOL	SPELLINGS	EXAMPLES
æ	*a*, ai	hat, plaid
eɪ, e	*a*, ai, au, ay, ea, eh, ei, ey	ate, rain, gauge, ray, steak, eh, veil, obey
ɛ:	*a*, ai, ay, e, ea, ei	dare, chair, prayer, there, wear, their
ɑ	*a*, e, ea	father, sergeant, hearth
b	*b*, bb	bed, hobby
tʃ	*ch*, tch, te, ti, tu	chief, catch, righteous question, natural
d	*d*, dd, ed	do, ladder, pulled
ɛ	a, ae, ai, ay, *e*, ea, ei, eo, ie, oe, u	any, aesthetic, said, says, ebb leather, heifer, leopard, friend, foetid, bury
i	ae, ay, e, ea, *ee*, ei, eo, ey, i, ie, oe	Caesar, quay, equal, team, see, deceive, people, key, machine, field, amoeba
f	*f*, ff, gh, ph	feed, muffin, tough, physics
g	*g*, gg, gh, gu, gue	give, egg, ghost, guard, demagogue
h	*h*, wh	hit, who
ɪ	e, ee, *i*, ie, o, u, ui, y	England, been, it, sieve, women, busy, build, hymn
aɪ	ai, ay, ei, ey, i, ie, uy, y, ye	aisle, aye, height, eye, ice, tie, buy, sky, lye
dʒ	ch, d, dg, dge, di, g, gg, *j*	Greenwich, graduate, judgment, bridge, soldier, magic, exaggerate, just
k	*c*, cc, cch, ch, ck, cq, cque, cu, gh, *k*, qu	car, account, bacchanal, character, back, acquaint, sacque, biscuit, hough, kill, liquor
l	*l*, ll	live, call
m	chm, gm, lm, *m*, mb, mm, mn	drachm, paradigm, calm, more, limb, hammer, hymn
n	gn, kn, *n*, nn, pn	gnat, knife, not, runner, pneumatic
ŋ	n, *ng*, ngue	pink, ring, tongue
ɒ	a, *o*	wander, box
oʊ, o	au, eau, eo, ew, *o*, oa, oe, oh, oo, ou, ow	hautboy, beau, yeoman, sew, note, road, toe, oh, brooch, soul, flow
ɔ	*a*, ah, al, au, aw, *o*, oa, ou	tall, Utah, talk, fault, raw, order, broad, fought
u	eu, ew, o, oe, *oo*, ou, u, ue, ui	maneuver, grew, move, canoe, ooze, troupe, rule, flue, fruit
ʊ	o, *oo*, ou, *u*	wolf, look, should, pull
ɔɪ	*oi*, oy	oil, toy
aʊ	*ou*, ough, *ow*	out, bough, brow
p	*p*, pp	pen, stopper
r	*r*, rh, rr	red, rhythm, carrot
s	c, ce, *s*, sc, sch, ss	city, mice, see, scene, schism, loss
ʃ	ce, ch, ci, psh, s, sch, sci, se, *sh*, si, ss, ssi, ti	ocean, machine, special, pshaw, sugar, schist, conscience, nauseous, ship, mansion, tissue, mission, mention
t	ed, ght, *t*, th, tt	talked, bought, toe, thyme, bottom
θ	th	thin
ð	th, the	then, bathe
ʌ	o, oe, oo, ou, *u*	son, does, flood, couple, cup
ju, ɪu	eau, eu, eue, ew, ieu, iew, *u*, ue, ui; yu, yew, you	beauty, feud, queue, few, adieu, view, use, cue, suit; yule, yew, you
ɜr, ɝ	*er*, ear, ir, or, our, *ur*, yr	term, learn, thirst, worm, courage, hurt, myrtle
v	f, ph, *v*, vv	of, Stephen, visit, flivver
w	o, u, *w*	choir, quiet, well
j	g, i, j, *y*	lorgnette, union, hallelujah, yet
z	s, sc, ss, x, *z*, zz	has, discern, scissors, Xerxes, zone, dazzle
ʒ	g, s, *si*, z, zi	garage, measure, division, azure, brazier
ə	*a*, ai, *e*, ei, eo, *i*, ia, *o*, oi, ou, u	alone, mountain, system, mullein, dungeon, easily, parliament, gallop, porpoise, curious, circus
ər, ɚ	ar, *er*, ir, or, our, ur, yr	liar, father, elixir, labor, labour, augur, martyr

INTERNATIONAL PHONETIC ALPHABET is an indispensable tool in the study of infant speech. In it there is only one symbol for each of the elemental sounds that can be uttered by the human voice. A baby is able to make from one to six such elemental sounds during a single exhalation.

words The 10 words most often used in constructing the first sentence are: "I," "is," "it," "you," "that," "do," "a," "this," "not" and "the." Nouns and verbs at first are used more frequently than adjectives and connectives.

NOW the question of primary scientific interest is: Does infant speech exhibit any degree of orderliness in its development, in other words, are there any discernible natural laws governing the emergence of speech patterns? To an untrained observer, infantile babbling seems to be simply an amorphous mass of sound, incoherent, unintelligible, chaotic, at times monotonously repetitive, at other times in a marvelously complex state of flux On the face of it there seem to be hardly any regularities in it. Yet it has been found to be quite orderly, and its investigation has yielded a number of statistical laws

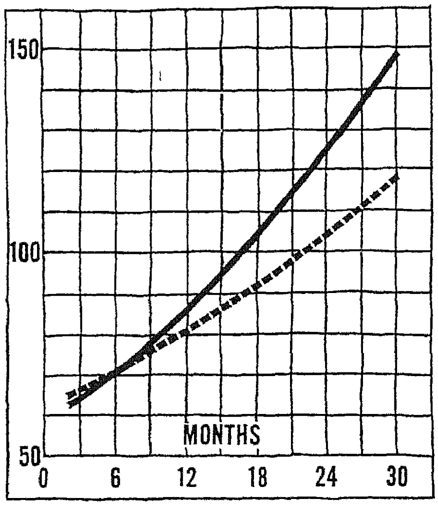
To understand this statistical analysis, a few definitions of terms used by workers in this field will help. The elemental speech sounds are called phonemes For present purposes a phoneme will be designated as a phoneme type. The vowel in the word "hat" is a phoneme type, as is each of the consonants in the word. The term type, then, refers to the speech sounds listed in the International Phonetic Alphabet. Another term employed is frequency, which refers to the number of times a type occurs.

Suppose we have painstakingly visited about 100 babies in their homes twice each month from birth to two and a half years of age At each visit all the sounds that the child utters on, say, 30 breaths have been recorded. Then our data will consist of sounds on 30 breaths for each of the 60 visits during the 30 months of the period studied For statistical convenience, instead of analyzing the progress of the 100 infants month by month, let us consolidate the data into two-month intervals or age levels. This will give us 15 age levels with which to work.

If we now average the number of phoneme types, or kinds of sound, uttered by the 100 babies at each of the 15 two-month age levels, we will find that the mean number increases from age level to age level. The number rises at a regular rate, which is defined by the following mathematical equation. $N=7.53A^{.471}$. N stands for the number of types, and A for the age This equation tells us that the number of phoneme types equals 7.53 times the age raised to .471 power, and that a curve plotted from this equation will be a parabola.

The curve affords a picture of the nature of speech development during infancy. It shows that infants during the first two months of life use on the average about seven and a half sounds. At the end of two and a half years, the average infant uses about 27 sounds. Now there are about three dozen phonemes in the International Alphabet The curve thus tells us that on the average the baby of two and a half years vocalizes only about two thirds of the sounds he will later use, so that the achievement of a full complement of the phonetic elements is still a matter of further development.

The curve also indicates that progress is not made in equal increments If the increments were equal, the curve would be a straight line It is, however, a decelerating curve, which means that although the baby continues to increase his mastery of new sounds, he does so at a steadily declining rate This matter of rate is important to parents The average parents are tremendously concerned to know whether their child is "keeping up," or why the youngster next door is "ahead of" their child. The equation,



DEVELOPMENT OF SPEECH in children of professional families (*solid line*) is somewhat faster than that of those in laborers' families.

then, is a precise formulation of a concern vital to every parent and, as we shall see later, may be used to establish a fairly accurate answer to a parent's questions about his child's progress.

In the acquisition of new sounds, infant girls show a superiority to boys. In the first year there are no sex differences in development, but thereafter there is an increasing tendency for girls to surpass boys.

When we consider the frequency, or the number of times the phoneme types are used, the situation is reversed. Now the boys advance more rapidly than the girls, in other words, they use fewer different sounds, but they do more talking. For both boys and girls, the frequency rates form accelerating curves, in contrast with the decelerating curves for phoneme types. This means, of course, that the babies use the sounds they have acquired more frequently as they grow.

Thus on the basis of two different criteria of speech development, we see that the early incoherent efforts of infants toward true speech are not as amorphous or as chaotic as everyday observation might suggest.

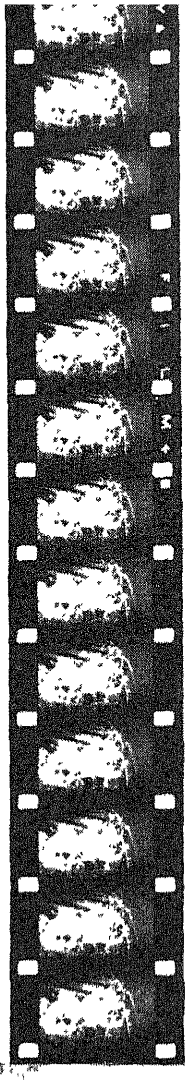
With the equations thus developed, we can study the differences in speech development of infants in different home environments A comparison of the speech of babies of working-class families with those whose fathers are doctors, lawyers, teachers or business owners is shown in the chart on this page. These curves are based on the frequency criterion of speech development By this criterion the speech development of babies in homes of workers is considerably below that of the professional group One suggested explanation is that the experience of the worker's child is more manual, while the environment in the professional household is highly verbal

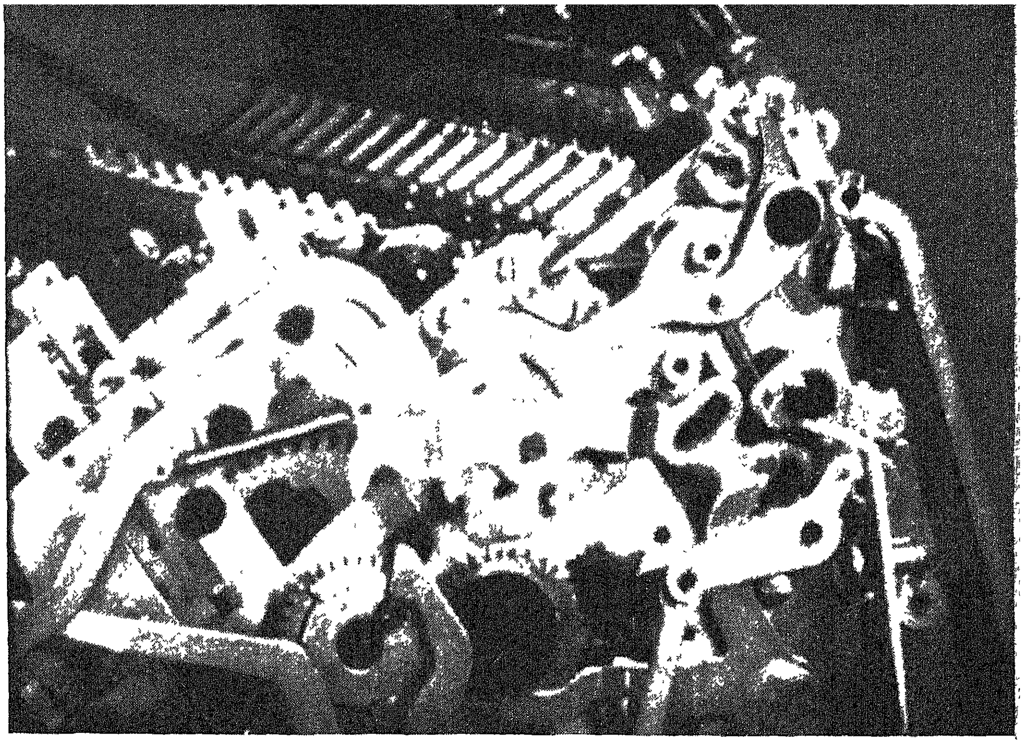
We have found that low-grade feeble-minded children, that is, idiots and imbeciles, in the fourth year of life possess the speech-sound status of year-old infants When these children were examined a year later, they had made no progress whatever This degree of speech retardation is practically hopeless. A study is now being made of what correlation exists between intelligence and speech development in normal infants.

If speech development is really subject to natural laws, it should be possible to diagnose the speech-sound status of any infant and determine whether it is retarded, normal or advanced Suppose a mother asks us to tell her whether her 18-month-old child is progressing normally in its speech development. The procedure would be to obtain several samples of the child's speech sounds from which to determine its average phoneme frequency. Suppose this value is 100. This would intersect the average curve for all children of 18 months at the 50th percentile, or the median, meaning that the child's development is perfectly normal. In fact, if its value fell between the 25th and 75th percentile lines, the infant's speech-sound status would be considered average. If the value fell between the 75th and 90th percentile curves, the child would be considered above average, above the 90th percentile it might be considered very advanced. If, on the other hand, it fell below the 10th percentile, the infant would be diagnosed as greatly retarded

It appears that at least some progress has been achieved in finding the answers to a few of the questions concerning the beginnings and subsequent development of speech in the human being. The next step in this enterprise is to discover remedial measures for babies whose speech seems to show retardation

Orvis C. Irwin is research associate professor of psychology in the Iowa Child Welfare Research Station at the University of Iowa.





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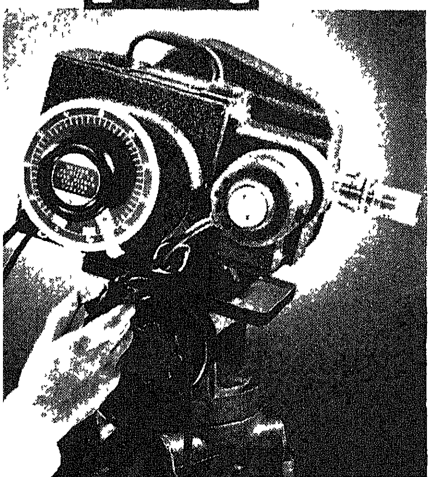

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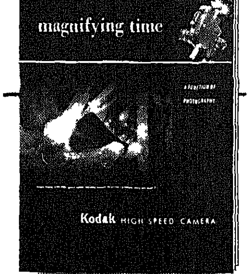

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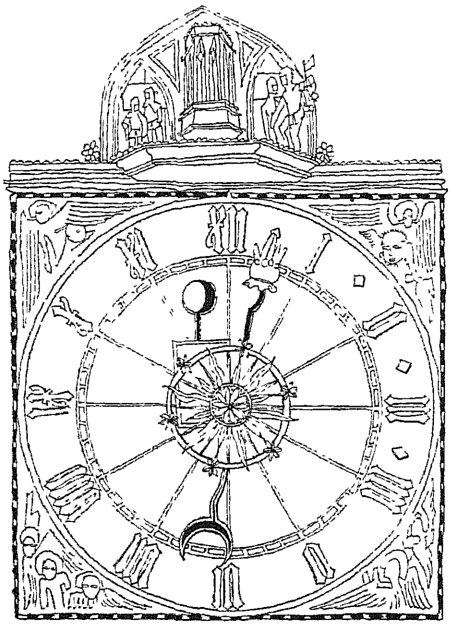


SCIENCE AND

Television and the Family

IN nearly two million U. S. homes, the flickering screen of the television set has paralyzed the family in its chairs. Obviously it is about time somebody began to measure the impact of this new social force, and some preliminary data are now at hand. Under the sponsorship of the Columbia Broadcasting System, the Rutgers University sociologists J. W. Riley, R. F. Cantwell and K. F. Ruttiger studied a sample group of 278 television-owning families in a small Eastern city for a period of two months and compared them with a like group of non-owners.

The investigation documented one fact of which parents were already aware. that television's most powerful impact is on the children. Youngsters with a set in the house average more than two hours of watching each evening—and are remarkably difficult to put to bed. One measure of its comparative fascination for children is the fact that in households without television sets the children average only half an hour of radio listening an evening.

The Rutgers investigators found that the acquisition of a television set cut heavily into the time a family spent in movie-going, listening to the radio and attending sports events—but after six months, when the novelty had worn off, attendance at sports events rose again. Television families also did much less visiting, and it was statistically demonstrated that they had more visitors. Apparently television did not greatly reduce a family's reading or participation in sports.

Perhaps the most surprising finding was the difference in the hold of television on different social groups. Ownership of television sets was of course proportionately higher in the higher income groups, but the proportion of low-income owners is rising. The investigators found, however, that families with little education lose interest in television programs sooner than the better educated. Among families whose adults had only a grammar-school education, 80 per cent were found using their television sets on any given evening during the first few months of ownership, but after six months the proportion dropped to 53 per cent In college-educated families, the use of the set dropped only from 74 per cent at the beginning to 67 per cent after six months.

Man Bites Publisher

U. S. PHYSIOLOGISTS have for years been kept busy defending themselves against the unflagging anti-vivisection campaigns of the Hearst newspapers, which have not only made it difficult to procure animals for research but have reflected on the personal character of many investigators. Last month the physiologists made the "man-bites-dog" type of news by taking the offensive against their attacker. Through the initiative of the National Society for Medical Research, their defense organization, they filed two million-dollar libel suits against William Randolph Hearst and the Hearst Publishing Company, Inc.

In one suit, N. R. Brewer, physiology lecturer and director of the animal quarters at the University of Chicago, asks damages because an article in Hearst's Chicago *Herald-American* described him as a "torturer," "sadist" and "cruel experimenter." The author of the other suit is Virgil H. Moon of the Wake Forest College Medical School. Some time ago the *Herald-American* quoted Moon as having said in an interview that animal experimentation is useless. The scientist declares that the interviewer "maliciously misrepresented his views" and seriously damaged his standing in his profession.

The National Society is preparing two more suits against Hearst. "Other suits will follow if necessary," said the Society's president, Anton J. Carlson of the University of Chicago. "Medical science refuses to be 'the goat' any longer for the ugliest and most baseless vilification campaign of our times. A counter-attack in the courts will be pursued to the utmost."

Atomic Energy

THE richest source of uranium in the Western world is the Shinkolobwe mine in the Belgian Congo. The mine is controlled and operated by a part-

THE CITIZEN

ly British-owned company, the Union Minière de Haute Katanga On August 1 the contract between this company and the U S Atomic Energy Commission, by which the U. S. has received its chief supplies of uranium, expired. This appears to be the chief precipitating factor behind the recent series of secret top-level discussions among U. S , British and Canadian officials on atomic energy policy.

Because of uranium's great strategic importance, the mineral has been removed from free commerce virtually all over the world Among the Western nations it is sold in a strictly closed, controlled market prices are fixed, and in effect all supplies are allocated by agreement between the U. S. and Great Britain. Thus the expiration of the Belgian Congo contract has provided the British with an effective occasion for asking for a review of their present limited participation in atomic energy developments.

The full partnership in this field that existed during the war among the U. S., Britain and Canada was radically altered by the Atomic Energy Act of 1946. The law ended the free exchange of information among atomic scientists of the three countries, and since then they have gone separate ways in their follow-up research Now the British want to resume a closer partnership. In return for continuing to allow the U. S. to buy the major output of the Belgian Congo mine, they apparently would like some information on recent U. S. work in atomic energy, including weapons, and perhaps some important U S.-produced materials, such as plutonium. The British very likely have also pointed out that they can offer, as an additional *quid pro quo,* some valuable information that they and the Canadians have developed in their atomic energy research.

The situation has all the makings for a solid impasse in the coming months. President Truman has assured Congress that no secret information will be given to the British without the consent of Congress. Two members of the Joint Congressional Committee on Atomic Energy—Senators Bourke B. Hickenlooper of Iowa and William F Knowland of California—have announced their opposition to giving such information. If the British were to take an equally uncompromising position on Belgian Congo uranium, U. S. uranium sources would become severely limited. Many U. S. political strategists doubt, however, that the British would go so far, in view of their need for Marshall Plan assistance.

In the sixth semi-annual report of the Atomic Energy Commission, issued last

month, the Commission laid some stress on its work in developing uranium resources in Colorado. It reported that there was enough uranium in the carnotite rocks there to supply U. S. needs. But the carnotite ores are of such low grade that an investment of hundreds of millions of dollars would be required to extract the metal in sufficient quantity.

Meanwhile three researchers announced that they had developed a new process for purifying thorium, another potential source of nuclear fuel. Thorium can be converted into fissionable uranium 233. It is a plentiful element, large amounts of it are available in black beach sands in Brazil and India. The metal has been difficult to purify because it has a tendency to form gelatinous compounds that clog chemical apparatus and hold large amounts of impurities. The new process, devised by Louis Gordon and C. H Vanselow of Syracuse University and H H Willard of the University of Michigan, produces dry thorium salts.

The AEC's sixth semi-annual report announced continued gains in improving the production and reducing the costs of the fissionable materials uranium 235 and plutonium. It also disclosed that the Western Electric Company and Bell Telephone Laboratories had taken over, as contractors, the operation of the AEC center at Sandia, N M., which has now become the principal center for the manufacture of atomic bombs.

The sixth semi-annual report was devoted in the main to a review of the AEC's work in biology and medicine. Its chief item of news the maximum safe limit of exposure to radiation, which has been one tenth of a unit per day since the beginning of the atomic energy project, is to be reduced to about half of that amount—three tenths of a unit per week. AEC investigators recently discovered that a tenth of a unit of radiation per day may reduce fertility and produce tumors in animals.

U.S.S.R. Steel Plunge

STEEL technicians in the U. S. have experimented for some time with the use of oxygen to improve the efficiency of blast furnaces. They have shown that enrichment of the blast with oxygen substantially increases a furnace's production of pig iron. But because the technique requires expensive alterations in existing blast furnaces and has not demonstrated any appreciable saving of coke, it is still considered only an experiment in the U. S.

Now the U.S.S R. is reported to be making a bold investment in the idea. It is said to be spending the equivalent of $2 billion on the construction of new steel plants in the Donbas and Soviet Asia that will use the oxygen process. The authority for this report is Gerald Oster, physical chemist of the University of London, who described the

project in the *Annals* of the American Academy of Political Science.

Peter Kapitza, the U.S.S.R.'s leading physicist, is said to have designed a turbine that will produce pure oxygen cheaply and in large quantities. According to the Russians, the oxygen blast furnace technique that they have developed, the details of which are not stated, reduces the cost of steel-making by 25 to 30 per cent.

Another major technical development, which may have a direct bearing on the U.S.S.R. project, has been reported by Norway. This is a process that may vastly increase the supplies of coke. A large part of the world's bituminous coal resources have hitherto been classed as "non-coking." These coals break up into dust when they are heated with conventional coke-making processes that drive off the water and volatile organic substances. A way to make coke from "non-coking" coals, developed by a Norwegian electrochemical firm, was reported to a recent world-wide scientific conference at Lake Success sponsored by the United Nations. Bituminous coal is crushed and pressed into briquettes, which are then heated slowly in an electric furnace. The resulting coke briquettes meet the exacting requirements of a blast furnace. The process is practical wherever cheap water power is available.

Sun's Closest Neighbor

ASTRONOMERS have hunted in vain for centuries for some body in the solar system that might approach the sun more closely than the planet Mercury, whose mean distance from the sun is 36 million miles. Now Walter Baade of Palomar Observatory has found one. It is an asteroid, only nine tenths of a mile in diameter, which in its great elliptical orbit sometimes comes within 22 million miles of the sun.

In the 19th century an obscure French village doctor named Lescarbault claimed the discovery of a new planet between Mercury and the sun. The supposed planet, named Vulcan, was believed to account for certain unexplained perturbations in Mercury's orbit. But Lescarbault's planet was never found by any other observer. In 1878 the University of Michigan astronomer James Craig Watson saw two planetlike bodies near the sun during an eclipse, and during the same eclipse Lewis Swift, another American astronomer, reported seeing a third body. None of the three was ever seen again, however, and astronomers concluded that they were actually stars. The mystery of Mercury's apparent perturbations was finally cleared up by Albert Einstein's revision of Newtonian gravitation in his general theory of relativity.

The new asteroid, found with Palomar's big Schmidt photographic tele-

scope, is certainly not one of the objects seen by Watson or Swift. It is too small to have been detected with their equipment. Discovery of the asteroid will help to determine the mass of Mercury more precisely. The asteroid's football-shaped orbit varies in distance from 22 million to 156 million miles from the sun. Its closest approach to the earth is four million miles.

The Bee Work Goes On

THE remarkable studies of the language of bees by the Austrian zoologist Karl von Frisch [SCIENTIFIC AMERICAN, August 1948] have evoked both admiration and skepticism among biologists. One of the skeptics, the British zoologist W. H. Thorpe of Cambridge University, went to von Frisch's laboratory in Graz last year to see for himself. He returned an enthusiastic supporter of von Frisch's "astonishing" and "revolutionary" findings. In the British journal *Nature* he declares himself convinced by the Austrian investigator's "very impressive evidence."

Von Frisch has shown by a number of careful experiments that bees returning to a hive inform their fellow bees of the distance and direction of a feeding place by means of wagging dances on the comb. Using the sun as a point of reference, they indicate the direction by the angle at which they point in their dance on the vertical comb. Thorpe was most impressed with some recent work by von Frisch which proved that the bees are sensitive to polarized light in the sky. Even when they can see only a patch of blue sky from the hive, the bees can determine the position of the sun by the polarization of light from the patch of sky, and they change the direction of their wagging dances when the polarization changes.

Thorpe concludes. "The performance of the waggle dance on the vertical comb is so remarkable that we are forced to ask ourselves whether, apart from human faculties, there is anything comparable known in the animal kingdom; for I think it may be said that the performance of the worker hive bee is essentially an elementary form of map-making and map-reading. . . . [von Frisch's] work poses tremendous problems for the neurophysiologist and psychologist [and requires] a reconsideration of some of the most fundamental concepts used in our explanations of the behavior of insects and other animals."

Cell Analyzer

A HIGHLY sensitive new instrument for analyzing the chemical composition of cells has been developed by Arthur W. Pollister of Columbia University. It makes use of the fact that proteins and nucleic acids, the most important

We hear on every side that the American Way of Life is in danger. I think it is. I also think that many of those who talk the loudest about the dangers to the American Way of Life have no idea what it is and consequently no idea what the dangers are that it is in.

You would suppose, to listen to these people, that the American Way of Life consisted in unanimous tribal self-adoration. Down with criticism; down with protests; down with unpopular opinions; down with independent thought. Yet the history and tradition of our country make it perfectly plain that the essence of the American Way of Life is its hospitality to criticism, protest, unpopular opinions, and independent thought. A few dates like 1620, 1776, and 1848 are enough to remind us of the motives and attitudes of our ancestors. The great American virtue was courage.

We ought to be afraid of some things. We ought to be afraid of being stupid and unjust. We are told that we must be afraid of Russia, yet we are busily engaged in adopting the most stupid and unjust of the ideas prevalent in Russia, and are doing so in the name of Americanism. The worst Russian ideas are the police state, the abolition of freedom of speech, thought, and association, and the notion that the individual exists for the state. These ideas are the basis of the cleavage between East and West.

Yet every day in this country men and women are being deprived of their livelihood, or at least their reputation, by unsubstantiated charges. These charges are then treated as facts in further charges against their relatives or associates. We do not throw people into jail because they are alleged to differ with the official dogma. We throw them out of work and do our best to create the impression that they are subversive and hence dangerous, not only to the state, but also to everybody who comes near them.

The result is that every public servant must try to remember every tea party his wife has gone to in the past ten years and endeavor to recall what representatives of which foreign powers she may have met on these occasions. A professor cannot take a position on any public question without looking into the background of everybody who may be taking the same position on the same question. If he finds that any person who is taking the same position on this question has been charged with taking an unpopular position on another question, the professor had better not take any position on this question, or he may be haled before some committee to explain himself.

Is this the American Way of Life? The great American word is freedom, and in particular, freedom of thought, speech and assembly. Asserting the dignity of man,

WHAT PRICE FREEDOM?

by **ROBERT M. HUTCHINS**

Chancellor of Chicago University

—at the 237th convocation—

and of every man, America has proclaimed and protected the freedom to differ. Each man is supposed to think for himself. The sum of the thoughts of all is the wisdom of the community. Difference, disagreement, discussion decided by democratic processes are required to bring out the best in the citizens. America has grown strong on criticism. It would be quite as consistent with the American Way of Life to offer prizes for the most penetrating criticism of our country as it would be to offer prizes to those who have done the best job of advertising it.

The heart of Americanism is independent thought. The cloak-and-stiletto work that is now going on will not merely mean that many persons will suffer for acts that they did not commit, or for acts that were legal when committed, or for no acts at all. Far worse is the end result, which will be that critics, even of the mildest sort, will be frightened into silence. Stupidity and injustice will go unchallenged because no one will dare to speak against them.

To persecute people into conformity by the non-legal methods popular today is little better than doing it by purges and pogroms. The dreadful unanimity of tribal self-adoration was characteristic of the Nazi state. It is sedulously fostered in Russia. It is to the last degree un-American.

American education has not been constructed on such un-American principles. In general, the practice has been to give the student the facts, to try to help him learn to think, and to urge him to reach his own conclusions. It is not surprising that the heart of American education is the same as that of Americanism: it is independent thought. American education has not tried to produce indoctrinated automatons, but individuals who can think, and who will think always for themselves. The basic principle of American government, and one that accounts for the importance of education in this country, is that if the citizens learn to think and if they will think for themselves, the Republic is secure. The basic principle of the Russian dictatorship is that the people cannot think or cannot be trusted to think for themselves.

The American doctrine rests on the proposition that it is the individual in himself that counts. It is not who his father was, or how much money he has, or what his color or creed is, or what party he belongs to, or who his friends are, but who and what is he? So the test of a teacher is whether he is competent. The professional competence of a teacher is hardly a question on which lay bodies, or even administrators or trustees, would wish to pass without the advice of persons professionally competent in the teacher's field.

If we apply any other test than competence in determining the qualifications of teachers we shall find that pressures and prejudice will determine them. In 1928 it was said that Al Smith could not be President because he would be subservient to a foreign power, and today in many places, and if not today it may happen tomorrow, anti-Catholic or anti-Jewish campaigns may mean that teachers who belong to those churches will not be able to practice their profession.

Teachers may be expected to obey the law of the land. But it is still permissible, I hope, to ask whether a law is wise. To discriminate against teachers—to act as though they were all disloyal—and to put them under special legal disabilities seems injudicious if we want able, independent men to go into the teaching profession.

The assumption appears to be that American education is full of Reds, an assumption that is the precise reverse of the truth. All the excitement of the last few years, all the hearings, investigations, and publicity releases, have not turned up more than four or five Communist professors, even though membership in the Party has been perfectly legal up to now. To require oaths of loyalty from all because of the eccentricity of an infinitesimal minority is an unnecessary and derogatory act. And of course it will not effect any useful purpose; for teachers who are disloyal will be dishonest; they will not shrink from a little perjury.

The way to fight ideas is to show that you have better ideas. No idea is any good unless it is good in a crisis. You demonstrate the failure of your ideas if, when the crisis comes, you abandon them or lose faith in them or get confused about them to the point of forgetting what they are. The American idea is freedom. Freedom necessarily implies that the status quo may come under the criticism of those who think it can be improved. The American idea is that the state exists for its citizens and that change in society must occur to meet their developing needs. The whole theory of our form of government is a theory of peaceful change. Many of the changes that Marx and Engels demand in the *Communist Manifesto* have taken place in this country, and they have taken place without communism, without dictatorship, and without revolution, thus disproving, incidentally, one of the central theses of Marx and Engels, that such things cannot be accomplished without communism, dictatorship, and revolution.

These reflections on the *Communist Manifesto* lead me to say that labeling some thing or some man communist because communists happen to favor it or agree with him, that easy process by which one disposes of different views by applying a dirty name to them, involves the negation of thought of any kind. If it had been applied consistently in American history it would have deprived us of some ideas and some men that we are proud to think characteristically American. For example, the *Communist Manifesto* demands free education for all. Are we therefore to recant, and renounce our doctrine for free education for all?

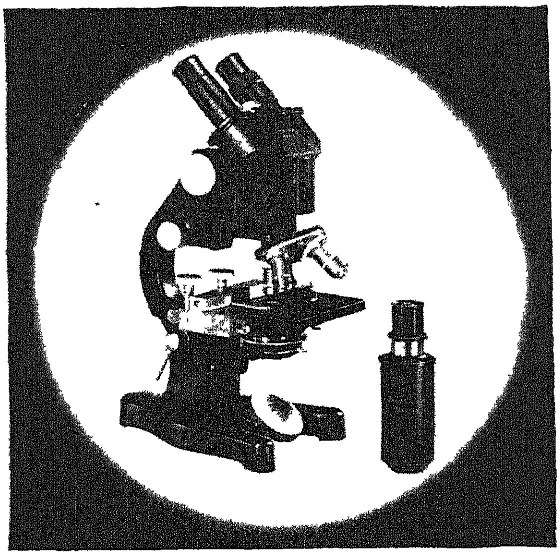
And what would the F.B.I. say of Thomas Jefferson, who calmly remarked in his First Inaugural, "If there be any among us who wish to dissolve this union, or change its republican form, let them stand undisturbed, as monuments of the safety with which error of opinion may be tolerated where reason is left free to combat it."?

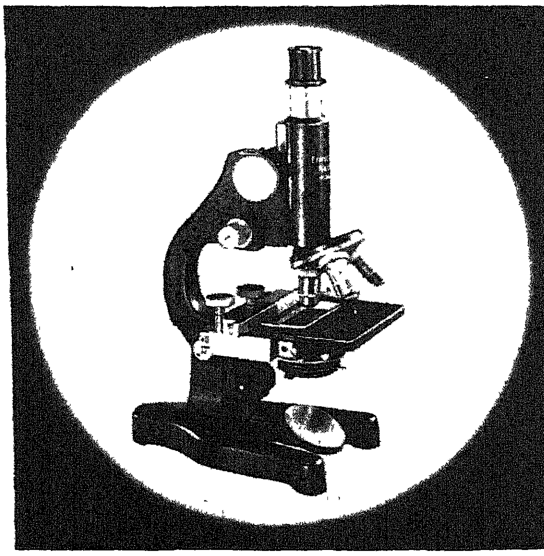
Jefferson was not in favor of revolution; he was serene in the face of talk of it because he had confidence in our people, in our institutions, in democracy, and in the value, power, and results of independent thought.

We are now in the midst of a cold war. We must protect ourselves against external enemies, their representatives in this country, and any citizens who may be conspiring to overthrow or betray the government. But the statute books are already filled with laws directed to these ends. It has never been shown that there are so many spies or traitors in this country, or that the external danger is so great and imminent that we have to divert the entire attention of our people into one great repressive preoccupation, into one great counter-revolution in which the freedoms of our citizens must be thrown overboard as too burdensome for the floundering ship of state to carry.

It is useful to remember that Jefferson spoke in 1801, when our Constitution was twelve years old, and when the infant republic was in dreadful danger from deep divisions within and from the wars that were raging between the great powers. If he was right in speaking in such a way at such a time, we cannot be far wrong if now, when America is the most powerful nation on earth, we seek to recapture some of his sanity and courage.

How is the educated man to show the fruits of his education in times like these? He must do it by showing that he can and will think for himself. He must keep his head, and use it. He must never push other people around, nor acquiesce when he sees it done. He must struggle to retain the perspective and the sense of proportion that his studies have given him and decline to be carried away by waves of hysteria. He must be prepared to pay the penalty of unpopularity. He must hold fast to his faith in freedom. He must insist that freedom is the chief glory of mankind and that to repress it is in effect to repress the human spirit.





compounds in the nucleus of a cell, absorb characteristic wavelengths of visible or ultraviolet light. The amount of light absorbed varies with the amount of the substance present. The instrument, known as a microspectrophotometer, directs a beam of light on a slice of cell material about one 2,500th of an inch thick. A photoelectric tube records how much light passes through the slice and, indirectly, how much is absorbed

Pollister and his co-workers are using the device to study the chemical changes in transplanted cancer tissues and the nucleoprotein unbalance that accompanies anemia. It is expected to be a valuable tool in all research involving precise measurements of chemicals in cells.

More Blood Fractions

THE discovery of methods for splitting blood into some of its component substances was one of the major medical advances developed during the recent war. This project, carried out largely at Harvard University, had to do with the plasma, or fluid, part of the blood. From it came fibrinogen, albumin, gamma globulin and other substances of great usefulness to medicine Another important step in the fractionation of blood, which may have equally useful results, has just been achieved Biochemists have developed a technique for separating, in undamaged, useful condition, the cell components of blood—red cells, white cells and platelets

The method was worked out by workers at half a dozen institutions under the aegis of the advisory committee of the American Red Cross national blood program. The problem was much more difficult than the separation of plasma In the handling of blood, the cells are vulnerable to injury in two ways: 1) When blood is extracted from a donor, the white cells and platelets are damaged by the wetting action of the tubing and container, 2) during the separation of plasma from cells in a centrifuge, the cells are damaged by their physical battering. The first of these problems was solved by lining tubes and vessels with a silicone, which does not wet the cells. The second was met by the use of chemical agents that produce selective sedimentation of the cells. Whole blood is first treated with the clotting agent fibrinogen, this brings down the red cells. Other sedimentation steps bring down the white cells and platelets separately.

The Red Cross also announced that a new technique for storing red cells will keep them viable for up to four months, instead of four weeks or less.

No one can yet predict what medical uses will be found for the cell fractions of the blood, but many of the fractions previously isolated have swiftly found application against various human disorders.

RADIO TELESCOPE at the Sterling, Va., station of the National Bureau of Standards is a big concave reflector that gathers radio waves from a small region of the sky. The observer sits in the cabin at the right. In his headphones radio noise from space is translated into a faint hissing sound. The amplitude of the signal is also recorded on a slowly traveling strip of paper. Much of the telescope is from a German "Giant Wurzburg" radar.

RADIO ASTRONOMY

The earth constantly receives broadcasts from the sun and the Milky Way. Yet the waves from the Milky Way are too strong to come from stars like the sun

by Grote Reber

UNTIL recently our knowledge of the universe was limited largely to the visual observations of classical astronomy. We are now beginning to get a more detailed view of the stars and interstellar space by means of a new instrument that discloses some of the invisible events taking place there. This instrument is radio. Essentially it is not very different from vision. A radio "telescope," like the eye or a camera, receives from the skies electromagnetic waves, which differ from light only in their wavelengths. But with the longer wavelengths of radio we can observe facts about the positions of stellar bodies and the matter in interstellar space that could never be seen with an optical telescope.

This new field is known as radio astronomy. Although it is widely supposed to have derived from advances in electronics during the last war, actually its history is somewhat older. The first investigator to suggest that radio waves might be coming to the earth from the skies was the British physicist Sir Oliver Lodge. He proposed in 1894 that Hertzian waves from the sun might be detected, and between 1897 and 1900 he attempted some experiments in Liverpool. He discovered, however, that even then the electrical "noise" in a large city was very great; thus his crude equipment was unable to pick out any radio noise from beyond the earth. Sir Oliver recommended that future investigations be conducted in the country (a recommendation which is now being followed by the National Bureau of Standards at its Radio Propagation Laboratory near Sterling, Va.).

Lodge's early suggestion was based on the theory, new in his day, that Hertzian (radio) waves, heat, light and X-rays are all different manifestations of electromagnetic waves. If light and heat waves came from the sun, why not Hertzian waves? He also reasoned that because much more heat and light came to the earth from the sun than from the rest of the stars put together, the sun's radio waves likewise should be more intense.

Yet when, in 1932, K. G. Jansky of the Bell Telephone Laboratories detected the first cosmic radio waves, he found that they came from the Milky Way, not from the sun. Jansky, who thus became the founder of the new experimental science of radio astronomy, had not been listening for cosmic radio messages. He was studying the direction of arrival of thunderstorm atmospherics by means of a rotating directional antenna tuned to a frequency of 20.5 megacycles. He noticed that even when atmospheric disturbances were absent he sometimes got small noise signals that apparently came from nowhere on earth. Eventually he determined that these nuisances, arriving from a variety of directions, all seemed to originate in the plane of the Milky Way. The sources always remained fixed with respect to the stars, indicating that the radio waves had a celestial origin. Jansky was able to determine the general direction of the waves and their intensity, but his equipment could not locate the sources of the waves precisely.

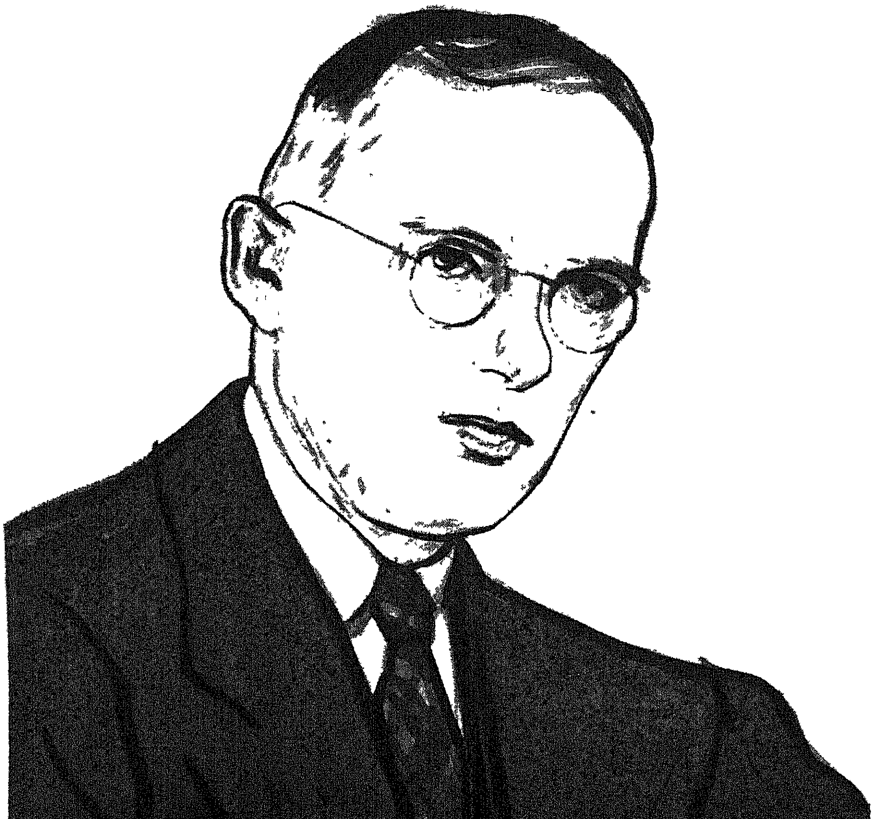
Stimulated by Jansky's work, the author undertook in 1936 to find out exactly where the galactic radio waves were coming from. Were they being generated in some of the bright stars of the Milky Way?

THE Milky Way is a giant aggregation of stars forming a disk that is shaped more or less like a watch. Our solar system, located toward an edge of the disk, may be imagined as a very small speck on the shaft that turns the second hand, about midway between the front and back faces of the watch. Consequently, as we look into the sky on a clear night, we see the bright band of the Milky Way arching across the sky, as if we were peering at the rim of a watch from the interior. In September it will arch overhead from southwest to northeast in the early evening as soon as the sky becomes black and stars are visible. This bright band, which looks more like an illuminated haze than a collection of stars, represents the collective luminosity of vast numbers of faint stars that the human eye is unable to resolve. On the other hand, when we look out toward the faces of the watch, *i.e.*, through the thin cross section of the Milky Way, there are not many stars in the line of sight, and the sky appears black.

To explore our huge galaxy for radio signals, the author constructed in 1937 at his home in Wheaton, Ill., a large radio receiver that resembles some of the radar detection equipment used in the late war. It is essentially a radio-type meridian transit that collects high-frequency energy from space in a parabolic mirror, reflects the energy to an antenna within a drum, and feeds it to a wide-band high-frequency receiver.

This apparatus was used to sweep the whole region of the Milky Way within range at our latitude. Surveys were made at two different frequencies—480 and 160 megacycles. A group in England made another survey at 64 megacycles. All three surveys showed that radio waves from the sky cluster in or near the plane of the Milky Way. They further showed that radiation is most intense in

SIR OLIVER LODGE proposed in 1894 that radio waves from the sun might be detected. His attempts to detect the waves, however, were unsuccessful.



K. G. JANSKY of the Bell Telephone Laboratories first detected radio waves from space. He found that they came not from the sun but the Milky Way.

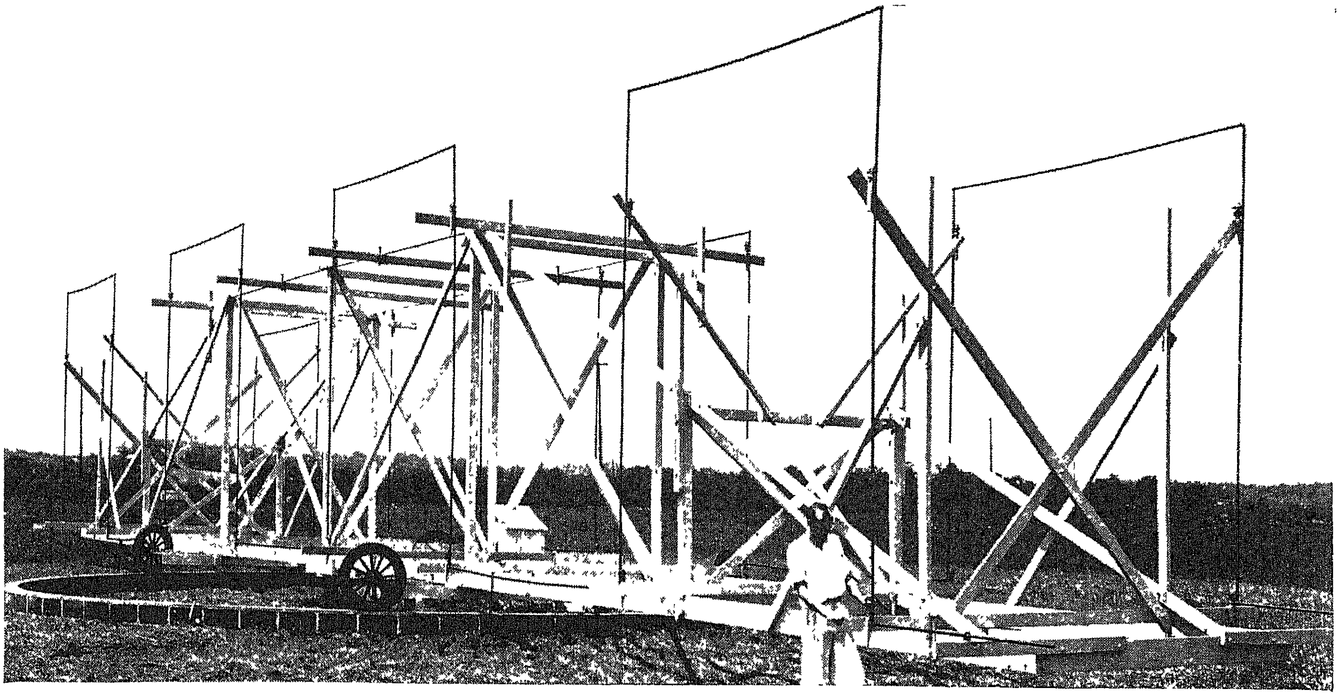
the regions of Sagittarius, Cygnus and Cassiopeia and from Canis Major to Orion. On September evenings Sagittarius is the brightest part of the Milky Way low in the southwest. Cygnus is overhead and may be identified by the large Northern Cross, the lower end of which points down the Milky Way toward Aquila and Sagittarius. Cassiopeia is a large W, which at this season lies on its side low in the northeast.

A remarkable feature of our observations was that none of the radio signals of greatest intensity came from the direction of the bright stars. This suggested very strongly that the galactic radio waves we receive from the Milky Way do not originate in the stars at all. Where, then, are they coming from? Can they be emanating from interstellar space? Strange as it may seem, that looks like the most probable source. It appears that they come from the great clouds of interstellar dust and gas in the galaxy.

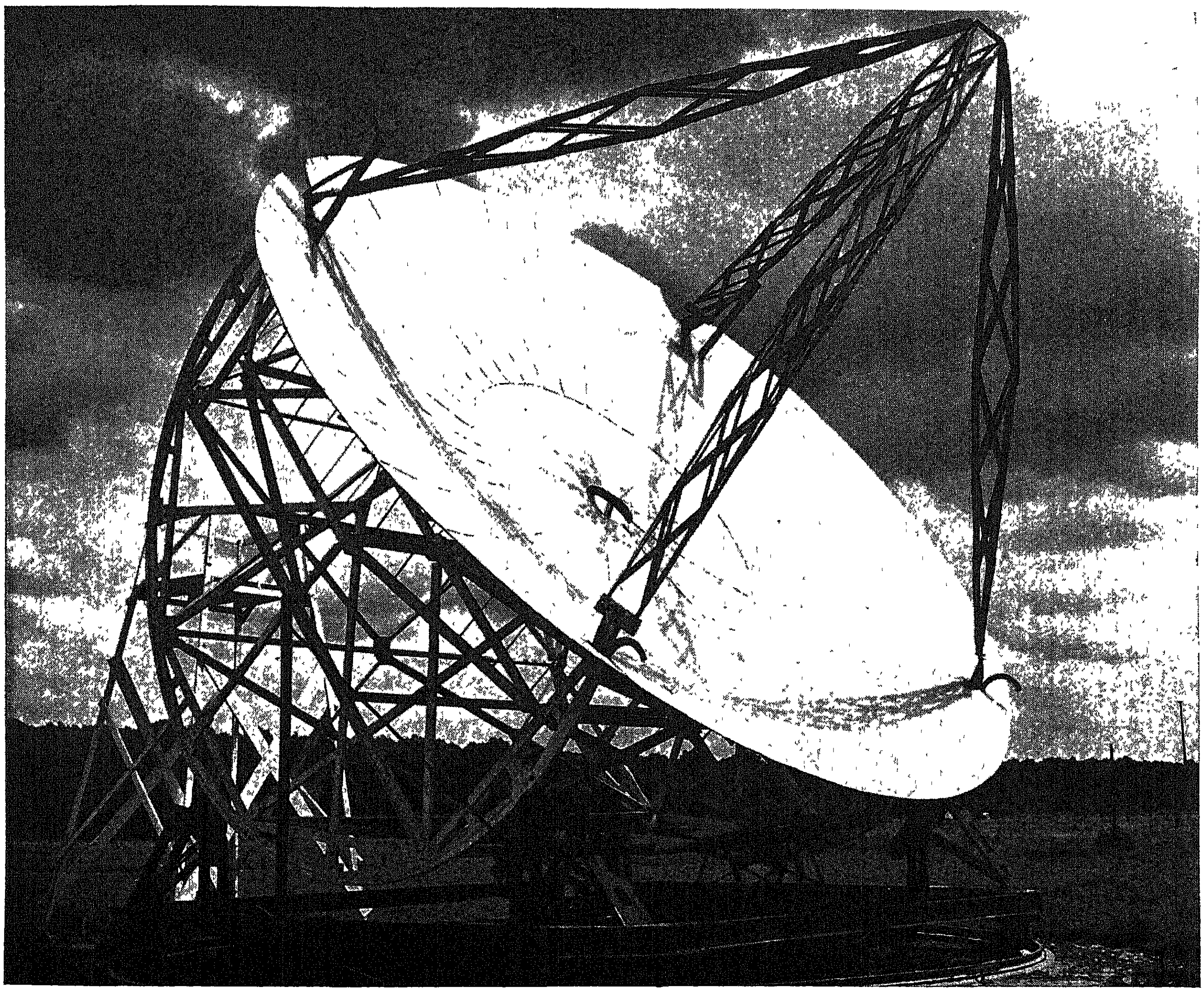
The broadcasts from these clouds may originate in the following manner. Under the action of starlight some of the gas atoms in such a cloud are ionized. The positive ions and free electrons that result may then interact, when they encounter one another, in such a way as to release radio energy. One possible method of interaction between them is known as the free-free transition. The particles do not meet but behave like certain large free bodies in the solar system. An electron, coming within a positive ion's region of influence, swings around it in a wide, eccentric orbit like a comet around the sun. The ion bends the electron's path and reduces its velocity. This loss of velocity is equivalent to a loss of energy, and the lost energy is radiated as radio waves.

The energy output of such a series of reactions under interstellar conditions cannot be tested in the laboratory, for in the vast, thin dust clouds of space the distance of an electron's travels between successive encounters with positive ions may be as great as the radius of Jupiter's orbit around the sun. But calculations based on the known distribution of interstellar gas show that the energy produced by reactions of this kind would be of the correct order of magnitude to account for the measured intensities of radio waves received by our equipment.

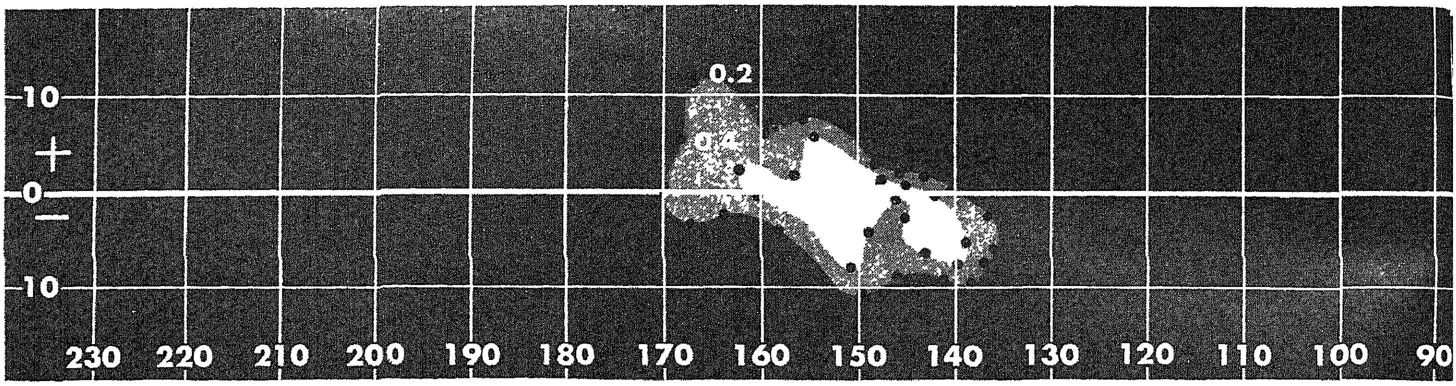
AT radio wavelengths the interstellar gas appears as a radiant haze. By tuning in at various wavelengths, we can control the distance we "see" into this haze, and map the various regions in it. Just as red light penetrates fog better than blue light, so radio waves vary in penetration—except that in the case of radio frequencies it turns out that the shorter waves, rather than the longer ones, have greater penetrating power. Thus the "maps" of radio intensity recorded by the author's radio receiver



JANSKY'S APPARATUS was set up in 1932 to detect radio disturbances in the atmosphere, but he noticed that it picked up radio noise when such were absent. The apparatus located only horizontal direction of noise.



AUTHOR'S APPARATUS was built in 1936 outside his home in Wheaton, Ill. Here it is photographed in its present location at the Sterling station of the Bureau of Standards. Receiving apparatus at focus is not in place.



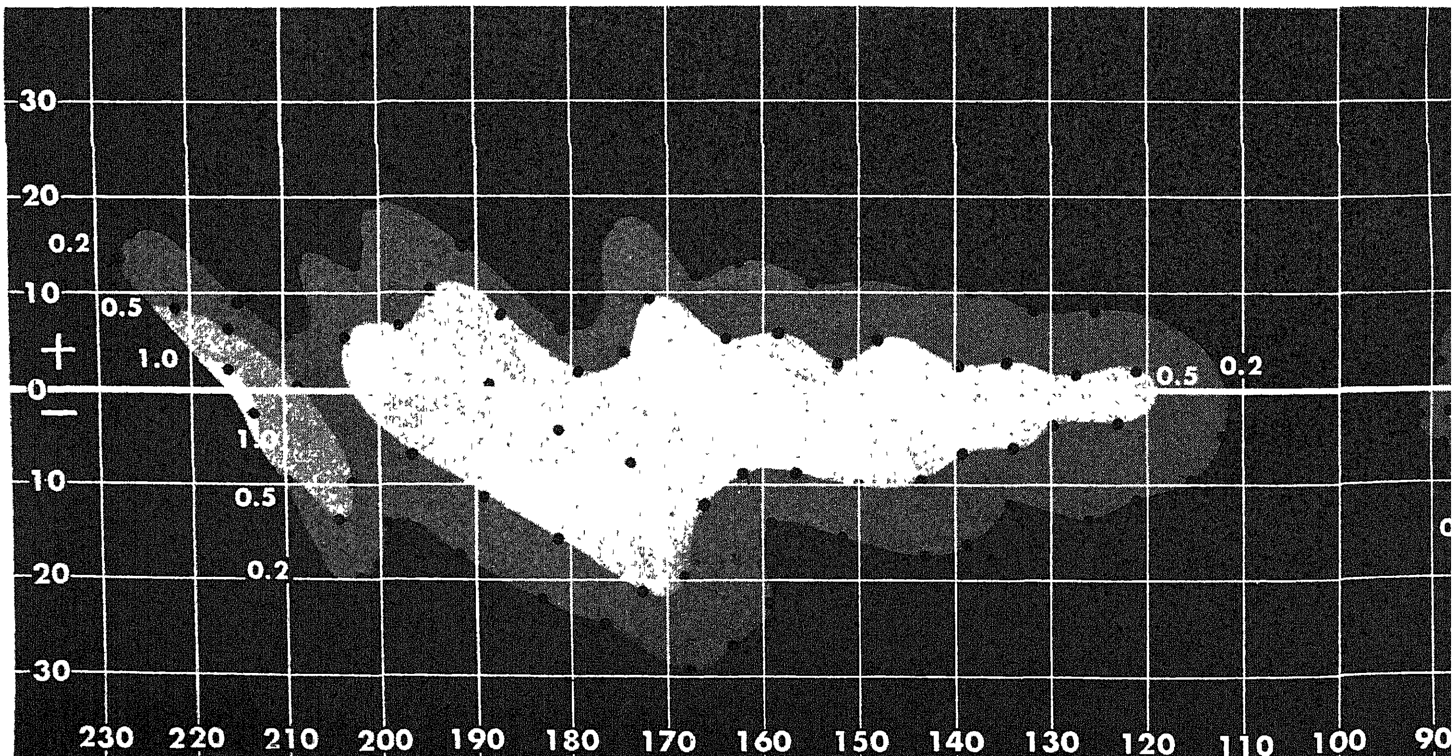
480-MEGACYCLE RADIATION from the Milky Way is plotted in contours from the author's observations (*black dots*). Figure 0 at left denotes galactic circle, a line drawn down the middle of the Milky Way. Hori-

may be interpreted as cross sections of the Milky Way at different distances The distances to the various cross sections are more or less proportional to the radio frequencies used.

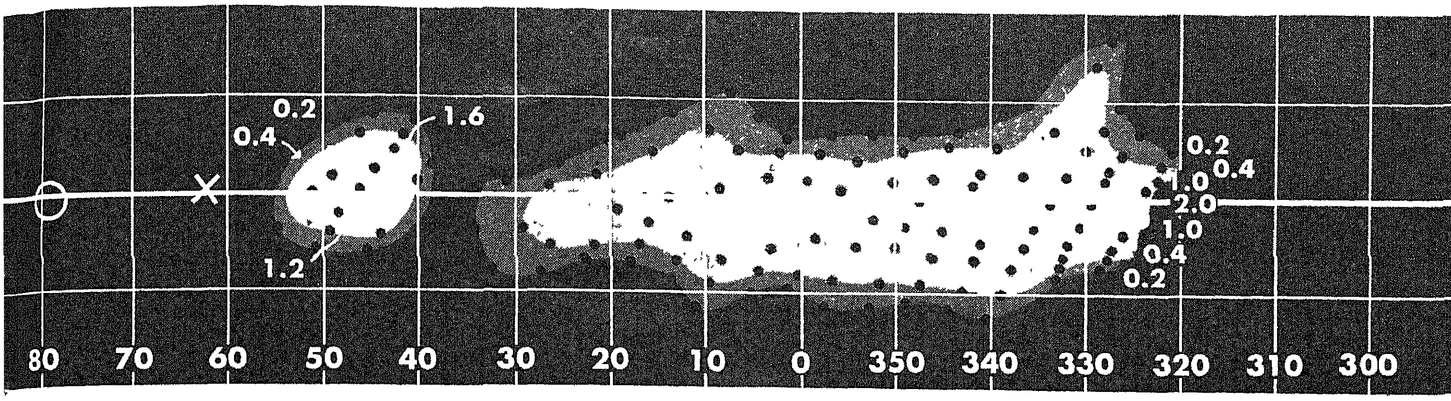
These maps show radiation from wide areas of the sky. A more pin-pointed inspection of the Milky Way discloses another extraordinary fact. As we have pointed out, no concentrated beams of radio energy come from the visible stars. But there are certain small spots in the Milky Way that do yield intense radiation. No bright stars are present to account for it. The small spots are tiny enough to be considered "radio stars." Though invisible to us, they represent powerful concentrations of energy like visible stars.

One such star was located accurately by G J. Stanley and J. G. Bolton of Australia. Using a radio receiver at 200 megacycles, they found an intense source of radiation, not precisely measurable but certainly less than a few seconds of arc in diameter, in the constellation of Cygnus near 43 degrees galactic longitude and plus five degrees galactic latitude. Only faint stars, invisible to the naked eye, exist in this area. M Ryle and F. G. Smith in England discovered a similar radio star in Cassiopeia at 78 degrees galactic longitude and minus one degree latitude These Australian and British investigators have turned up several other objects of the same kind elsewhere in the galaxy. They are out toward the rim of the Milky Way and seem to be more intense at the lower radio frequencies, which may indicate that they are relatively near us. The Australians have just reported in *Nature* (July 16) that their recent observations indicate that one of the radio stars may be associated with the Crab Nebula, which is believed to be the expanding shell of an old supernova.

WHEN we observe that no particularly intense radio energy comes to us from the bright stars, that does not mean that they generate no radio waves at all. Actually we can record some radiation at radio frequencies from the nearest star—the sun. Jansky failed to detect it because his radio equipment was not sufficiently sensitive. The intensity of the sun's radio waves is far below anything Lodge imagined. But with more sensitive receivers solar radio waves were detected by G C Southworth of the Bell Telephone Laboratories in 1942, and by the author in 1943 These observations,



160-MEGACYCLE RADIATION has contours rather similar to those at 480 megacycles. The brightest radio regions are in Sagittarius (11.2), Cygnus (3.4) and Cassiopeia (2.0). Longer 160-megacycle waves do not



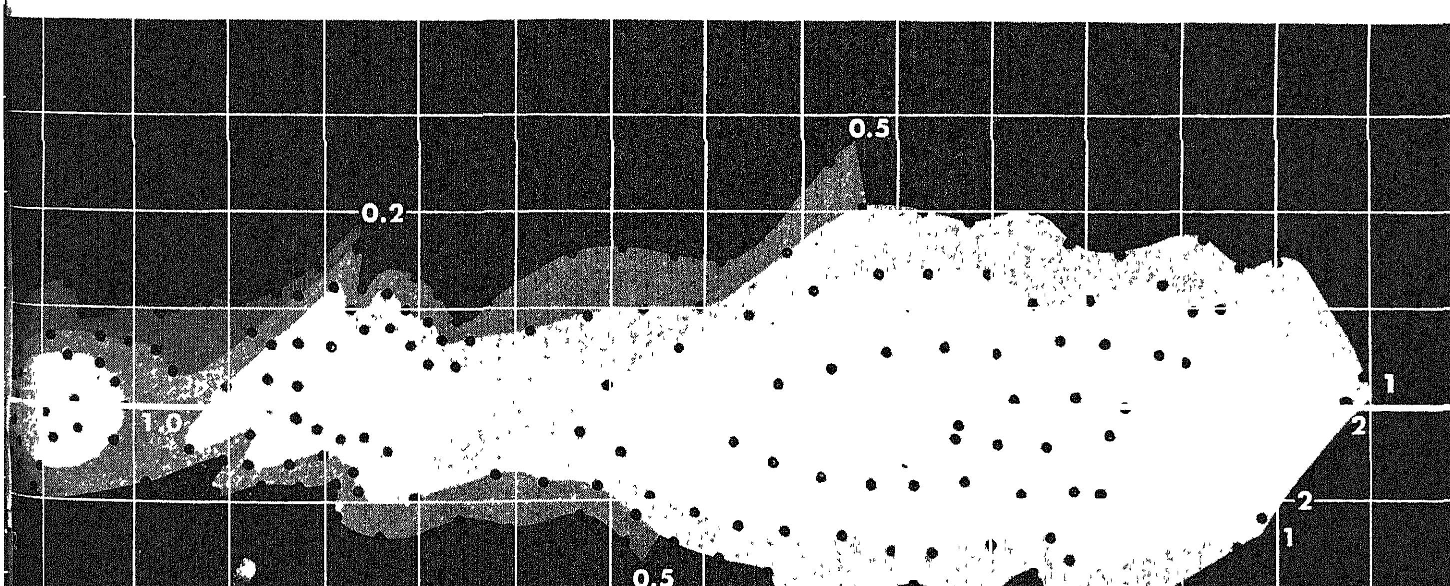
zontal lines mark galactic latitude; vertical lines, galactic longitude. Orion is in the middle of opposite page; Aquila in the middle of this page. Circle and cross to the right of center mark small sources of radio noise.

recorded at frequencies of 3,000 megacycles and 160 megacycles respectively, were made during a period of minimum sunspot activity, when the sun is most quiescent. It therefore appeared that the sun's radio radiation, like its light, was more or less constant, and investigation of its radio waves did not seem particularly promising.

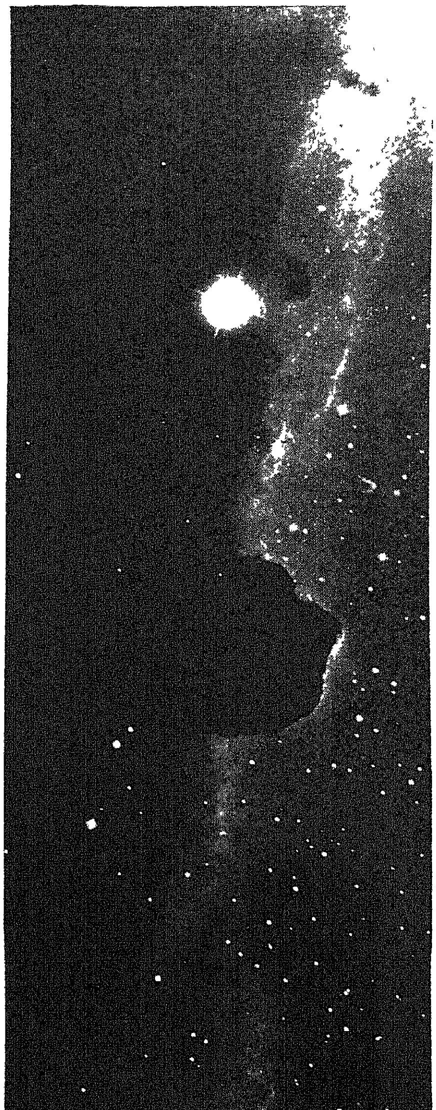
Soon after the end of the war, however, investigators began to report that upon rare occasions the radio waves from the sun are extremely strong—several hundred or a few thousand times the steady background intensity. These solar radio outbursts have been studied by many investigators, particularly in England, France, Australia, Canada, Germany and this country, over a frequency range from 60 megacycles to 38,000 megacycles. The tremendous variety of results obtained shows that the sun presents very complex phenomena in the region of radio wavelengths.

The sun, as we all know, is surrounded by a corona composed of a very tenuous and highly ionized gas. Thus the atmosphere of the sun is similar to the radiant haze that pervades the galaxy, although of course it is much smaller. For this reason we can "look" farther into the sun at the penetrating higher frequencies of radio than at the lower ones. Obviously in any complex turbulent mass of gas such as the sun the phenomena at different levels will be different. Furthermore, the sun will appear larger at the lower frequencies, because more of it is opaque to those frequencies. During the total eclipse of the sun on May 20, 1947, investigators from the U.S. Naval Research Laboratory and observers from the U.S.S.R. proved this fact. With the moon as a shutter, it was possible to estimate the size of the solar atmosphere. The U.S. observers, focusing on the sun from a boat in the South Atlantic at a radio frequency of 10,000 megacycles, found that its apparent diameter was only about 2 per cent greater than that of the moon. The Russians, observing at 200 megacycles, found it to be about 40 per cent greater than that of the moon. In other words, at 10,000 megacycles we can observe radio activity close to the sun's visible surface, or photosphere; at 200 megacycles we detect radio waves originating farther out in the corona.

RADIO waves have been found associated with at least two well-known solar phenomena. One is solar flares, the brilliant eruptions on the sur-



penetrate the interstellar haze as well as 480-megacycle waves. Contours at 160 megacycles accordingly show a cross section of a radio-emitting region in the Milky Way closer to earth than that detected at 480 megacycles.



HORSEHEAD NEBULA in Orion is an example of dust cloud that may emit radio waves. Photograph by 100-inch reflector at Mount Wilson.

face of the sun that apparently are due to the ejection of very hot material from the interior. There are two possible ways in which flares might cause radio outbursts. It may be that the exceedingly hot material in a flare simply radiates more energy at all wavelengths, radio as well as visual. The other possible explanation is that the mechanical energy of the hot flare, during its motion through the surrounding gases in the solar atmosphere, is converted into electromagnetic energy.

The second solar phenomenon with which radio waves are connected is sunspots. To the eye or a camera, a sunspot appears dark, because it is at a lower temperature than its surroundings. At radio frequencies, contrarily, the spot appears bright. This is primarily because the spot has a magnetic field. The field fans out from the spot somewhat like water out of a lawn sprinkler. It interacts with the surrounding ionized gas and creates a little radiant bulb over the spot. The bulb sends out strong radio waves. The size of the bulb over any given spot depends on the size of the spot, the strength of its magnetic field and the radio frequency at which it is observed. At very high frequencies, the bulb contracts or disappears. At low frequencies, the bulb becomes fainter, expands and finally is lost in the turbulence of the inner corona.

SOLAR radio waves have considerable practical interest for the National Bureau of Standards. One of the duties of its radio division is to make monthly predictions of the radio weather, that is, the conditions for radio reception, three months ahead. To gather information for these predictions, this country and others maintain radio weather stations at various places on the earth. Long-distance radio communication depends on conditions in the ionosphere, and these in turn depend on the activity of the sun. Thus radio weather depends upon the sun. Obviously it is important that the sun and its vagaries be understood if the radio weather predictions are to be accurate. To keep a constant watch on the sun it will be necessary to have at least three solar radio observatories, spaced approximately eight hours apart in time around the earth. The first of these has already been constructed at Sterling, Va. Others are now being considered.

Galactic radio waves have not yet achieved the practical importance of solar radio waves. The "cosmic noise" of the Milky Way does not affect long-wave broadcasting frequencies. It begins to be noticeable only at about 15 megacycles. But this brings it within the range of television and other very high-frequency transmission. On a television screen cosmic noise may produce flickering and "snow." Thus as the higher frequencies come into increasing use in communication and radar, the galactic radio waves may become a growing nuisance.

On the constructive side, they offer a means of studying great aggregations of astronomical material, most of which is not even detectable by telescopes or any other method. The work is only beginning, however, and we have a long way to go before we can explain in detail how these galactic radio waves are produced and how our new information fits into the visual picture of the sidereal universe. There is a great host of questions pressing for answers. For example, the Magellanic Clouds near the south celestial pole should be given special attention. It is possible that they may provide a yardstick of distance for radio astronomy, just as their pulsating stars, the Cepheid variables, already have for visual astronomy. The skies must be probed over a wider range of frequencies and with radio telescopes of higher resolving power.

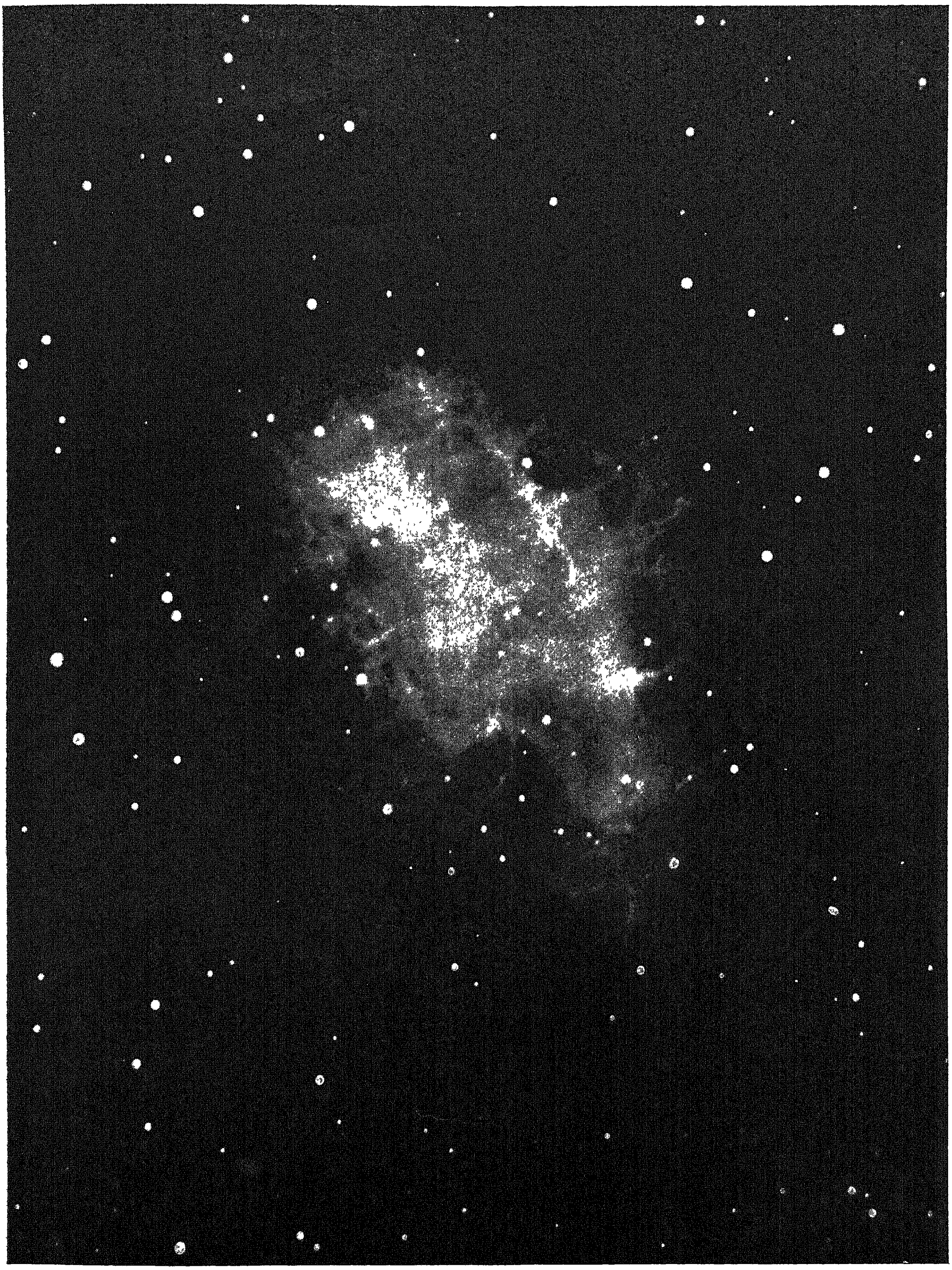
To make these studies over the entire sky, the observatory should be set up near the equator. Fortunately radio waves are immune to atmospheric disturbances such as rain, clouds, or fog, so a dry, clear climate is not necessary, as it is for a visual telescope. However, studies of the radio stars will require the use of the sea as a reflecting plane. For this reason the best location for a radio observatory would be a high mountain on an island or on the north-south coast of a continent.

We do not know much about galactic radio waves in the Southern Hemisphere, because few experiments have been conducted there. Yet this region is one of the most interesting, for some of the brightest and darkest spots of the Milky Way are visible there. Moreover, in that location the center of the Milky Way is high in the sky.

Exploration of the Southern Hemisphere of the sky, the collection of more data on the precise location of radio stars and the relation between the frequency and intensity of their radiation, the defining of the shape of the gaseous radio regions in interstellar space, the spectra of these gaseous regions and their velocities are some of the problems immediately confronting the radio astronomers.

Studies of solar radio activity are in a similar elementary stage. We would like to observe it at varying depths in the solar atmosphere. We would like to know why there are great variations in radio intensity that cannot be accounted for in terms of sunspot or corona behavior. What we learn about the sun by tuning in on it may prove to be invaluable in predicting its behavior.

Grote Reber, a pioneer in radio astronomy, is now associated with the National Bureau of Standards.

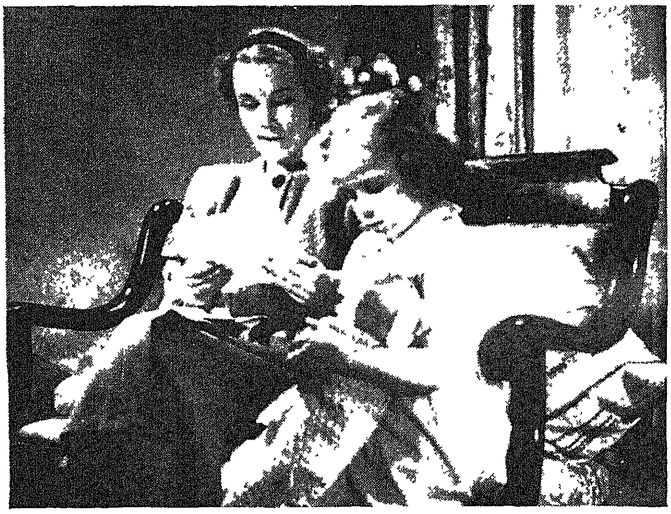


THE CRAB NEBULA has been suggested as the site of a small but powerful source of radio energy by the Australian investigators J. G. Bolton, G. J. Stanley and O. B. Slee. This object, which is in the constellation Taurus, appears to be the shell of a supernova that flared up in 1054 A.D. A new object as bright as Jupiter was described at that time by Chinese and Japanese. Photograph was made by 60-inch reflector at Mount Wilson.

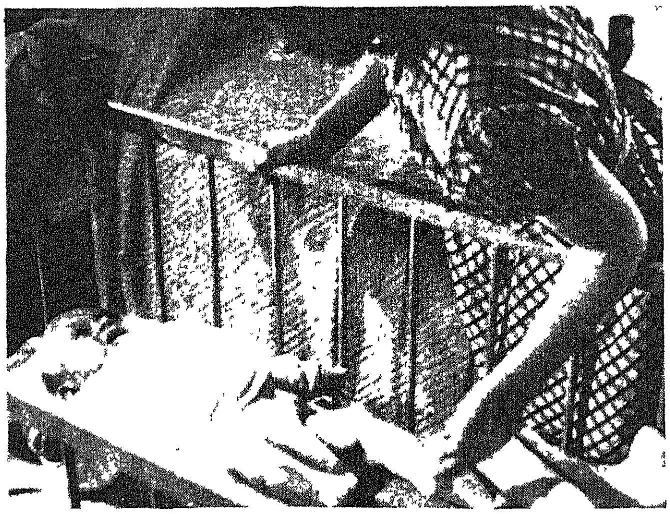
THE FEELING OF REJECTION recounts the life of Margaret, forced by her parents to be a "good little girl." Here she feels rejected upon the arrival of a new baby.

AS AN ADOLESCENT Margaret is afraid to make friends and to compete with other people. She lives through "best friend," who becomes interested in boys.

AS AN ADULT Margaret continues in the pattern of her childhood. When her superior at the office asks her to do some typing for another girl, she is unable to say no.



THE FEELING OF HOSTILITY considers problem of Clare. Here Clare's mother reads letter from her often absent husband. Clare feels loss of mother's attention.



WHEN MOTHER REMARRIES after husband's death, Clare resents attention mother and stepfather lavish on new baby. She pinches the baby's toe until it cries.

CLARE IS SUCCESSFUL because hostility to stepfather and other men is lessened by guidance in college. She is still, however, unable to form real friendships.

OVERDEPENDENCY is story of Jimmy, too zealously protected by mother and sister. Here his dependence on them causes him to be overly scared by tonsillectomy.

JIMMY FEELS SICK when he has to go to work. His wife, who protects him like his mother and sister, tries to wake him. He then goes to doctor instead of to work.

JIMMY BORROWS NICKEL from friend for telephone call. Film points out that overdependent people want favors. When they do not get favors, they demand them.

PSYCHIATRIC FILMS

Three fine Canadian documentaries portray the problems of rejection, hostility and excessive dependence

THREE remarkable short films have recently been produced by the National Film Board of Canada. They are psychiatric case histories entitled *The Feeling of Rejection*, *The Feeling of Hostility* and *Overdependency*. In them these common psychological problems are examined in an uncommonly accurate and straightforward way.

The Feeling of Rejection is the story of Margaret, a young woman who complains of headaches. Margaret is dominated by her family and her friends She does not like to give in to their demands, yet she cannot resist. The film traces the events that have formed Margaret's personality. During childhood her parents had repressed her so thoroughly that she learned little by experience. She could gain their approval only by yielding to them. In private discussions with a psychiatrist, and in group therapy, she learns the origin of her problem and gradually becomes more self-reliant.

The Feeling of Hostility is the life of Clare, an able and attractive young woman who is unable to enter into close relationships with other people. Clare's father had died when she was a child, leaving her dependent on her mother. When her mother remarried, Clare hated her stepfather because he shared her mother's attention. In *Overdependency* Jimmy, a young man who often feels tired and sick, is shown to be the result of a jealously protective mother and sister

The films, which were produced in collaboration with McGill University's Allan Memorial Institute of Psychiatry and Montreal's Royal Victoria Hospital, were made primarily for psychiatrists and their patients. They have been shown to college students, social workers, nurses and teachers. Audiences of educated laymen might also learn much from them.

DIRECTOR OF FILMS is Robert Anderson, here directing child who plays Jimmy. Films were made for Canadian Department of National Health and Welfare.

Pavlov

The great Russian physiologist was born 100 years ago this month. He caused dogs to salivate at the sound of a bell, and brought together physiology and psychology

by Jerzy Konorski

THIS month marks the 100th anniversary of the birth of Ivan Petrovich Pavlov. The great Russian physiologist, who died only 13 years ago, was one of those rare personages in science whose work is known in every country during his own time. Indeed, the character of his fame reminds one a little of the Pavlov dog whose mouth always watered at the sound of a bell. the mention of Pavlov's name instantly evokes in every literate person's mind the great contribution with which he is inseparably associated—"the conditioned reflex."

Pavlov's work left imperishable marks on physiology, neurology and psychology. Despite his wide fame, however, he was not intimately known outside his own country. His anniversary offers an occasion to tell something about Pavlov as a man and as a scientist. Obviously one cannot attempt to give a comprehensive review of his work in a single article, there will be set down here simply some personal recollections of Pavlov, and an estimate of some of his most important researches.

Pavlov was a man with obvious natural gifts—a brilliant mind, an incomparable memory, boundless energy and immeasurable enthusiasm—but with all that he remained to the end of his life a transparently simple human being His laboratory in Leningrad when I worked under him was a tumultuous beehive Pavlov was then over 80 years old; nonetheless he still possessed a vast enthusiasm for scientific investigation which he communicated to all those around him. He was the moving spirit in most of the laboratory's projects, and he would greet the successful completion of an experiment with a dance of joy His laboratory was operated like a town meeting; on Wednesdays his several dozen scientific associates gathered to discuss and argue their problems. Pavlov, who had a gift for dramatic narrative, fascinated his colleagues. He fought tooth and nail for his ideas against all arguments; but after he had cooled down he was quick to admit his error if his opponent turned out to be right

There is a story about Pavlov that illustrates amusingly his general attitude toward his work. During his early studies of the digestive system, he found that hydrochloric acid, when supplied to an animal's duodenum, caused the pancreas to secrete juice. Pavlov believed that the acid acted through some mechanism in the nervous system to produce this result. Some time later, however, the British physiologists Sir William Bayliss and Ernest H. Starling showed that the pancreatic secretion was initiated by a hormone mechanism. when the mucous membrane of the duodenum was stimulated by hydrochloric acid, it produced a hormone, secretin, which then acted on the pancreas. Pavlov at first pronounced this result incredible. When, having repeated the Bayliss-Starling experiments himself, he found that their conclusion was indeed correct, he exclaimed wrathfully, not in envy but in astonishment and self-reproach. "So we're not the only ones to make discoveries!"

PAVLOV was born in 1849 in the provincial town of Ryazan, in central Russia. He was the son of an Orthodox village priest, and inevitably was educated in a religious seminary. But he soon found that his interests lay elsewhere, and he transferred to the Faculty of Natural Sciences in St. Petersburg University. He went on to study medicine in the Military Medical Academy, graduating in 1879. While still a student, he began his first researches in the physiology of blood circulation. He was appointed to the staff of the Clinic for Internal Diseases. The head of the Clinic entrusted Pavlov with the responsibility of organizing a physiological laboratory to combine medical theory with practice in the Clinic. Except for a two-year period, 1884-86, during which Pavlov went to study with the German physiologist Carl F. W. Ludwig at Leipzig, he did most of his early work in this meager laboratory at the St Petersburg clinic

His facilities were of the most primitive kind The laboratory was a small wooden building, hardly more than a shed He had to finance his research largely out of his own very small salary He had no regular assistants. Nevertheless, by his own uncommon energy, assiduity and self-sacrifice he made rapid and fruitful headway, and his work won him a recognition out of all proportion to the modesty of his laboratory. In 1890 he was appointed to the chair of pharmacology in the Military Medical Academy, and in 1891 he was placed in charge of the physiological laboratory at the Institute of Experimental Medicine which was then being established in St Petersburg.

By the end of the 19th century Pavlov was generally recognized as one of the world's outstanding physiologists. In 1904 he was awarded the Nobel prize for his work on the physiology of digestion In 1907 he was elected to the Russian Academy of Sciences, and later he became the director of the Academy's Physiological Institute, which post he retained to the end of his life. In the 1930s a biological station was built for him in Koltuszi, now called Pavlovo, near Leningrad. He died of pneumonia in February, 1936, at the ripe age of 87.

OMITTING Pavlov's interesting but not preeminent early studies of the regulation of blood pressure, his lifework divides into two periods. From the 1880s to 1902, he devoted himself to detailed investigation of the functions of the alimentary tract. From 1902 until his death, he went on to explore a new branch of knowledge which he himself created—the physiology of higher nervous activity.

As is well known, Pavlov's research work on the secretory function of the alimentary tract became the lasting foundation of our present-day knowledge in this field. In these studies, as well as in his later investigations of the

nervous system, he was guided by certain ideas which, while not entirely original with him, he perhaps developed most consistently.

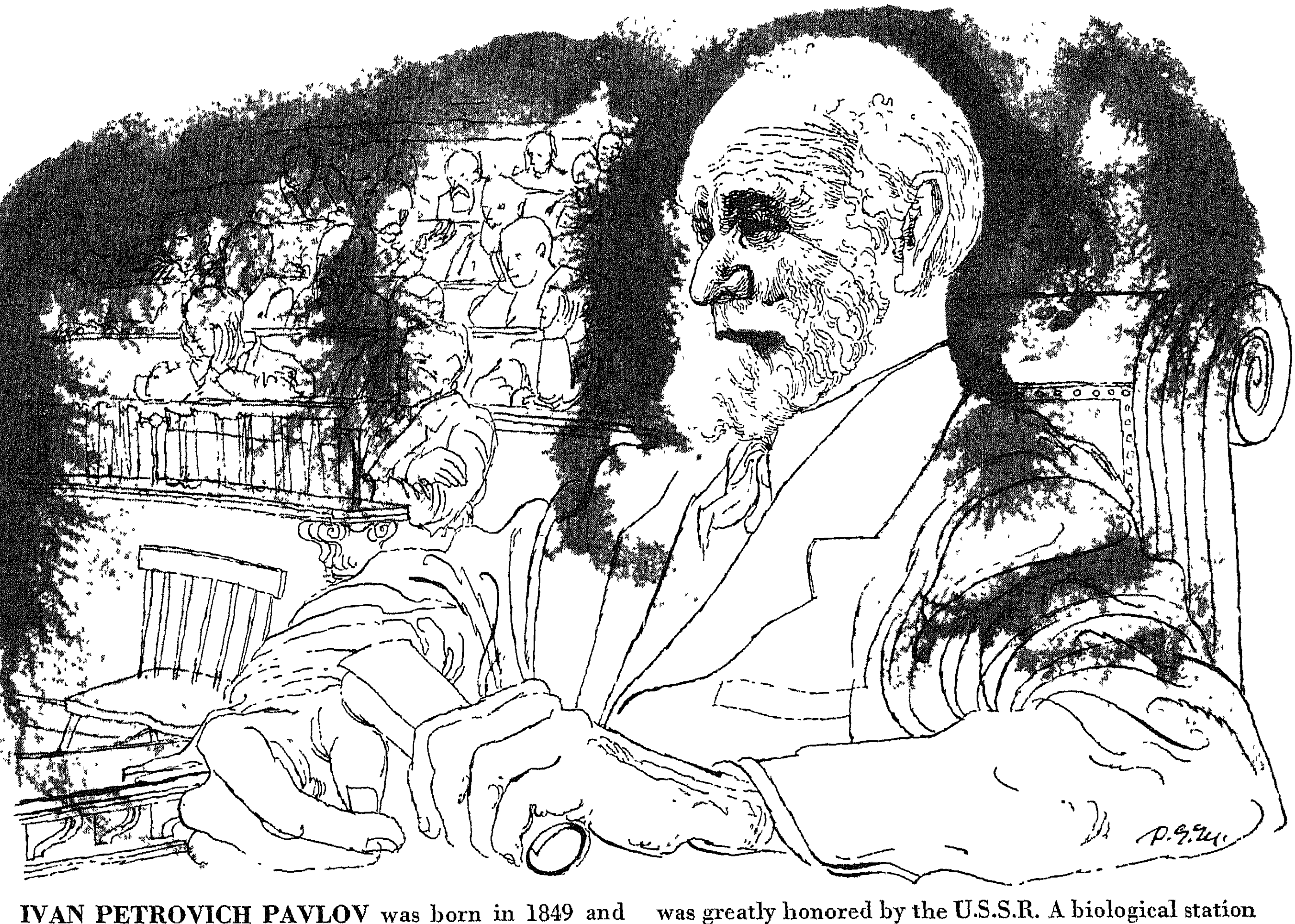
The first of these principles was that the organism functions as an integrated whole, and that the investigation of separate organs in the artificial conditions of isolated experiments cannot provide an adequate idea of how those organs act in their normal situation Hence Pavlov tried to carry out his physiological experiments in conditions approximating the normal as closely as possible. In his work on the alimentary tract he resorted to a number of ingenious operations to maintain the normal functioning of an animal's organs while exposing them to observation For example, he developed a method of exposing the ducts of the salivary and pancreatic glands without removing the organs from the body. He learned how to isolate a part of an organ without detaching it from the nervous system. One of his typical operations was the so-called "Pavlov pouch." In this operation, performed on a dog, one part of the stomach is isolated and formed into a blind pouch, with an opening to the abdominal wall. The nervous network of the pouch is uninjured, so that its secretory function is an exact replica of the functioning of the rest of the stomach, to which food passes. and it can be examined with great precision.

Obviously to make such operations come off successfully and keep the animals healthy Pavlov had to develop aseptic operating conditions and facilities for proper care of the animals after the operation Today the existence of such adjuncts is taken for granted, but in those days the idea was quite novel

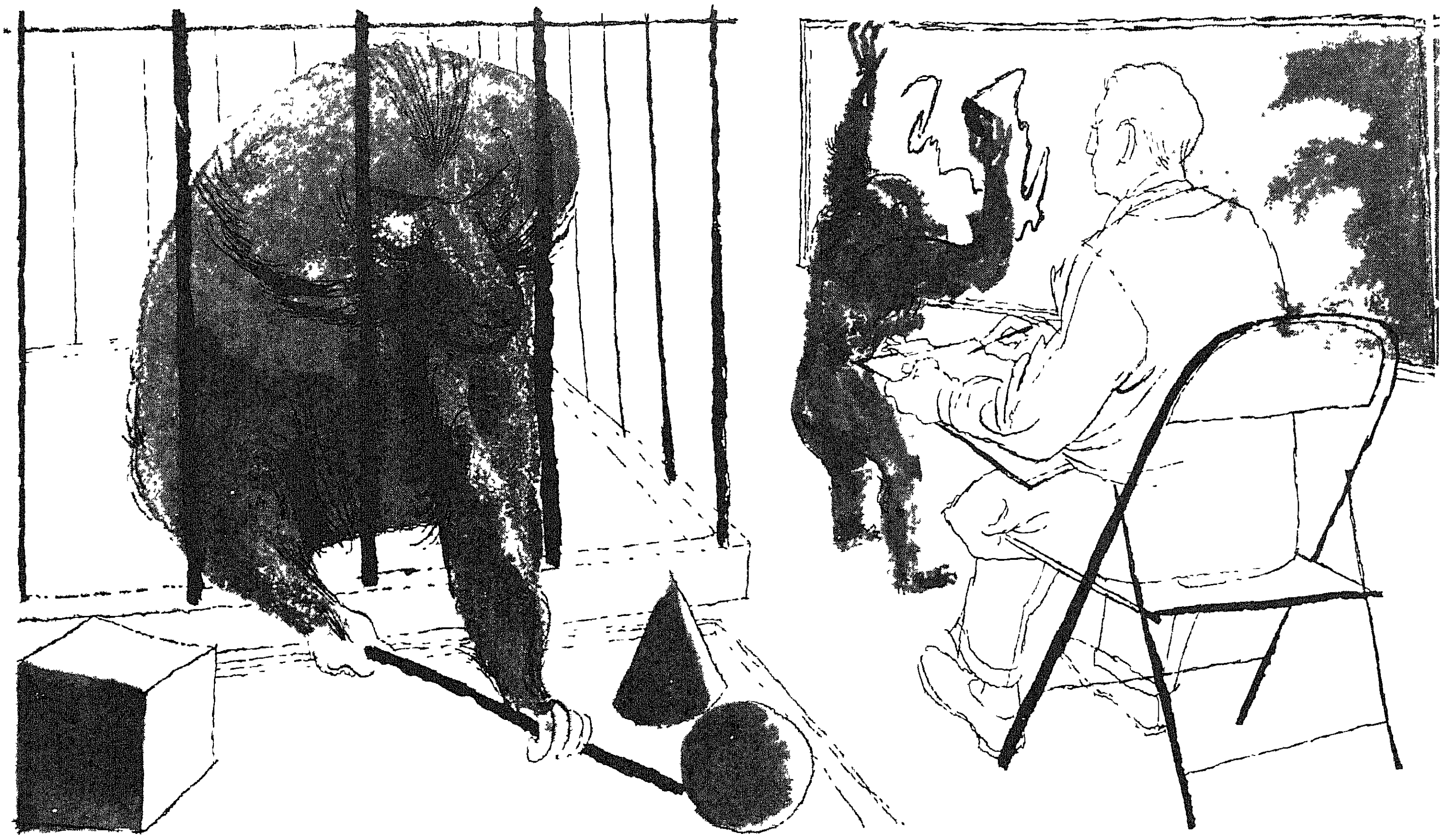
Pavlov's second guiding principle was what he called "nervism," meaning the hypothesis that all functions of the body were controlled by the nervous system. It must be remembered that in those days the study of endocrinology was only in its beginnings Pavlov believed that the nervous system was the only mechanism regulating and integrating the organism's activity, and so in all his researches he concentrated on elucidating the role of the nerves One of his most beautiful experiments was a set of operations on a dog's gastric system to investigate the mechanism of secretion by the stomach. He severed the dog's gullet from its stomach so that the food it ate would not pass into the stomach but fall outside the body. He also made a tubular opening into the stomach to examine its behavior He found that even though no food actually entered the stomach, it still secreted gastric juice, being powerfully stimulated by the animal's chewing and other acts of eating. And Pavlov proved that this reaction was mediated by the vagus nerves, for if these nerves were cut, the gastric secretion elicited by the act of eating stopped immediately. Pavlov's devotion to the theory of the central role of the nervous system helps to explain his incredulity and astonishment at the later discovery by Bayliss and Starling that hormones also play a part in the process of digestion.

The third principle that strongly motivated Pavlov's work was his conviction that physiological experimentation was of great significance for practical medicine. This idea, accepted without question today, was not so universally recognized then; at any rate not, so far as I know, in Russia

PAVLOV'S switch to the nervous system and the investigation of conditioned reflexes, which marked the second phase of his career, was a natural sequel to his work on the digestive system During that work he had been impressed by the discovery that a dog secretes saliva and gastric juice not only as the result of direct action of the food on the mucous membranes of the mouth and stomach,



IVAN PETROVICH PAVLOV was born in 1849 and died in 1936. He was awarded a Nobel prize in 1904. He was greatly honored by the U.S.S.R. A biological station was built for him at Koltuszi, which is now called Pavlovo.



PAVLOV'S BIG LABORATORY at Koltuszi was crowded with fellow workers and experimental animals.

Today the laboratory continues in the Pavlov tradition. At the left a baboon manipulates a stick during a study

but even in response to the mere sight of food, or to other signals heralding feeding This indicated that gastric secretions, which Pavlov had considered a purely physiological phenomenon, might also have a psychological basis and be related to the dog's experiences.

To a physiologist this was then a shocking idea. Up to that time physiology and psychology had been regarded as two entirely separate fields Physiology was concerned solely with the innate responses of the body, mainly those controlled by the lower parts of the nervous system, while psychology dealt only with acquired or learned responses Pavlov was confronted with a vexing problem. Must he now give up physiological methods and turn to psychology to investigate the dog's gastric behavior? This he could not bring himself to do, for he could see no way to verify theories in the realm of psychology by means of experiment.

After long hesitation and tormenting irresolution, Pavlov found a characteristically imaginative and resolute answer to his dilemma: He would attack the psychological problem with purely physiological methods. After all, the secretion of saliva or gastric juice was exactly the same phenomenon whether it had a directly physiological origin or a psychic one. By applying physiological experiments to the investigation of acquired behavior, he might open up an enormous new field of study.

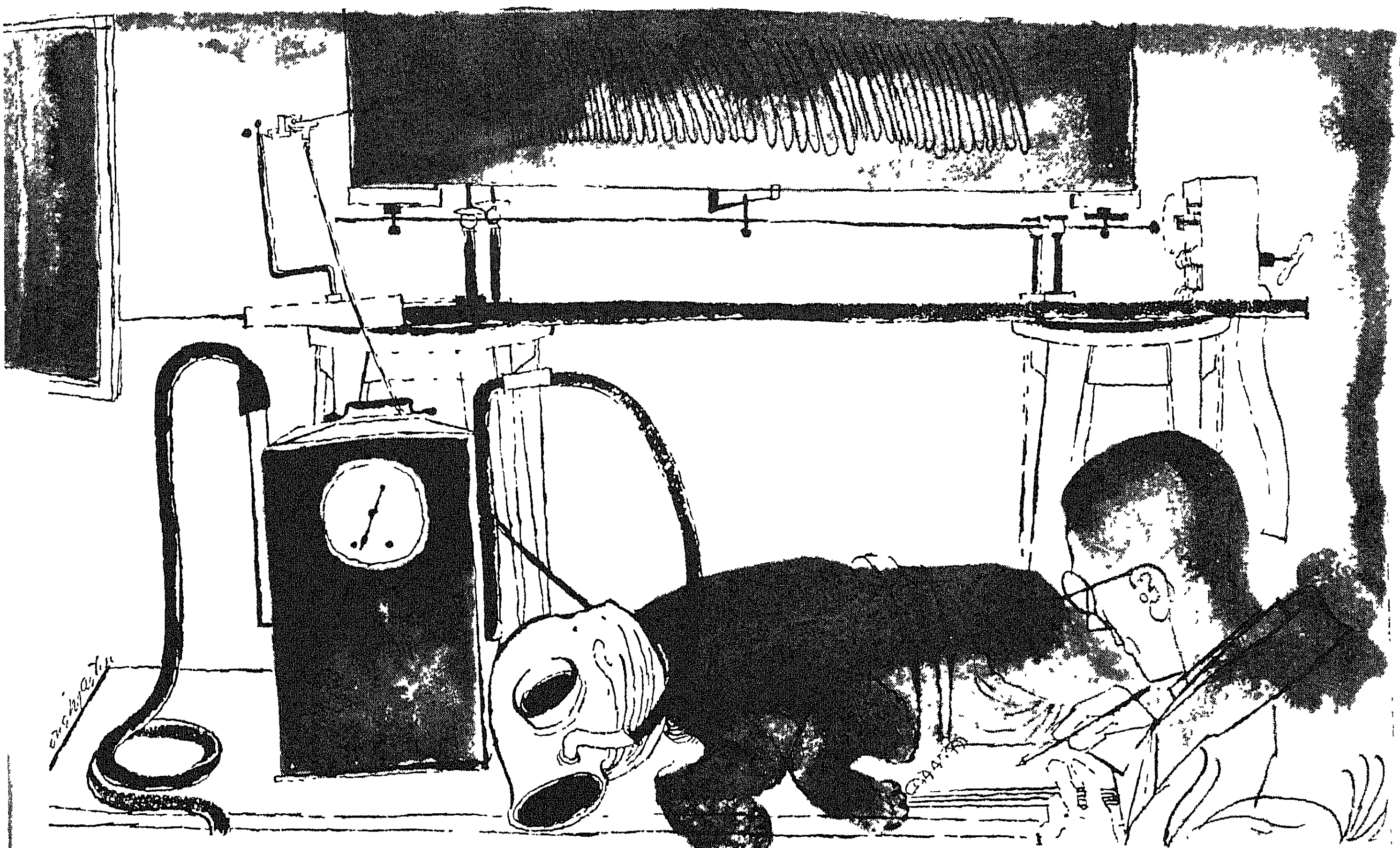
For several well-considered reasons, Pavlov chose the salivary glands as the focus of his experiments. He knew from previous research that the salivary gland is a very sensitive and selective reacting mechanism. Moreover, its activity is much more restricted and specific than that of the motor organs, the chief effectors of acquired behavior. Above all, Pavlov judged that investigation of the salivary glands would involve much less danger of anthropomorphic and psychological interpretation of the results, an error he wished to avoid at all costs.

So Pavlov and his collaborators began their studies of acquired, or, as he himself called them, conditioned (in Russian "conditional") reflexes The first experiments were made on "natural" conditioned reflexes, those established spontaneously in an animal in response to the sight and the smell of food, and so on. Only later, as the method was perfected, did the Pavlov group begin to develop conditioned reflexes to special signals, such as the beat of a metronome, the ringing of a bell, or the lighting of a lamp.

An important early finding in these experiments was that conditioning works two ways: it can inhibit as well as produce a response. When a conditioned stimulus ceases to be "reinforced," *i.e.*, to be accompanied by the presentation of food, the conditioned reflex is extinguished. Pavlov showed that this extinction is effected by a special mechanism which he called internal inhibition.

During the first period of research the Pavlov group occupied themselves chiefly with the properties and interrelations of the excitatory and inhibitory conditioned reflexes Later they extended the investigation to two new and important spheres. First, they showed by repetition of identical experiments on a great many dogs that animals vary greatly in the speed with which conditioned reflexes are formed, their permanence, the influence of inhibitory on excitatory reflexes, and so on. This provided a basis for the development of a classification of types of nervous system, a subject which has been worked at extensively of recent years. Attempts have even been made at the Biological Station in Pavlovo to show that an individual's type of nervous system may be inherited. Secondly, at the end of the second decade of research into conditioned reflexes the Pavlov investigators came quite accidentally upon the discovery of a neurotic state in dogs, caused by a conflict between excitatory and inhibitory reflexes.

The latter finding led to extensive investigation of so-called experimental neuroses, their pathogenesis, symptomatology and therapy. In these experiments



of motor reflexes. In the center an experimenter observes a monkey in the laboratory of higher nervous activity. At the right another experimenter tabulates a dog's respiratory responses with the help of a kymograph.

the salivary conditioned reflexes proved to be a very sensitive and precise indicator both of normal and of pathological nervous conditions. Toward the end of Pavlov's life a psychiatric and a psychoneurological clinic were attached to his laboratories, and in these the attempt was made to analyze various cases of human neuroses by resort to the laws discovered in experiments on animals. Thus even in this long, difficult and fundamental inquiry Pavlov realized his lifelong hope of applying his experimental research on animals directly to human pathology.

I have summarized in general outline the main scientific achievements that Pavlov and the physiological school he created have given us. So far as his researches into the physiology of digestion are concerned, there is no need to stress their value. But it is more difficult to estimate the value and scope of the science of conditioned reflexes.

It is generally accepted that conditioned reflexes have played a very considerable part in the development of modern psychology, and today there are whole trends of psychological investigation based to a large extent on the achievements of the Pavlov school. But, since the psychological applications of conditioned reflexes have been developed mainly in the U. S., I do not think that I, a European far removed from the centers of these trends, am competent to discuss them. As for the practical applications of the Pavlov achievements to the fields of psychoneurology, psychic hygiene and teaching, it is still too early to estimate their ultimate importance. And so I shall confine myself to surveying the significance of conditioned reflexes to neurophysiology itself.

Pavlov often called his teaching on conditioned reflexes "the true physiology of the brain." For him the study of conditioned reflexes was not an end in itself, but rather a means for understanding the central mechanism controlling them, namely, the cerebral cortex. Pavlov conceded that other methods of investigation of the activity of the cerebral cortex, such as electrical stimulation of the cortex in an anesthetized animal, could be very valuable, but he held that the true picture of this activity could be obtained only by studying the normal functioning of the organ, as in conditioned-reflex experiments. He was strengthened in this conviction by the fact that his view had been thoroughly and brilliantly justified in his work on the alimentary tract.

It is an interesting fact that Pavlov's attitude and methods were closely related to those of a great British contemporary, Sir Charles Sherrington (*see page 56*). Both Sherrington and Pavlov based their physiological studies on work with quantitatively and qualitatively defined stimuli and their combinations. Both investigated the central mechanism of reflexes by examining the reactions of animals. But in Sherrington's case the preparation studied was a spinal animal, whereas in Pavlov's it was an animal with the cerebral cortex intact, and Sherrington studied the innate activity of the nervous system, while Pavlov was concerned with its acquired activity.

Sherrington's experimental work was developed further by a host of neurophysiologists who, with the aid of more refined methods than were at Sherrington's disposal, brought greater precision into the notions of central excitatory and inhibitory states with which Sherrington operated. Pavlov's work has not been followed up as thoroughly as Sherrington's. If Pavlov's method of investigation of higher nervous activity is successfully linked up with, and enriched by, the modern tool of electroencephalography, just as Sherrington's method of study of lower nervous activity was later enriched by the recording of action potentials of the spinal cord, then perhaps Pavlov's statement that his work represented "the true physiology of the brain" will be fully justified.

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ENZYMES IN TEAMS

Biochemists have traditionally labored to isolate and observe individual enzymes. The author describes significant new work which indicates that these biological catalysts act in concert

by David E. Green

TO explain the living process by dissecting it into the simplest possible units—this is the objective of modern biology. The major focus in biological investigation has steadily narrowed from the living organism to the cell, from the cell to single molecules. And among all the substances isolated in this quest for the fundamental essences of life, none has been studied more minutely than the crucial catalysts known as enzymes.

The living process is an expression of myriads of chemical reactions, but virtually all of them have this one factor in common: they cannot proceed without the help of enzymes. It has been the hope of enzyme chemists that by isolating the individual enzymes, they might eventually be able to reproduce in the test tube every chemical process that takes place in the living cell. About 1,000 different enzymes have been isolated, and much has been learned about how they function. Perhaps the most spectacular triumph of classical enzyme chemistry has been the reconstruction with isolated enzymes of the entire process by which glucose or glycogen is fermented or broken down to lactic acid. The fermentation of glucose in the test tube, as reconstructed through the agency of combinations of some 20 isolated enzymes, is practically indistinguishable from the process as it occurs in the cell.

Yet in spite of these apparent reconstructions of complex life processes, there has been a growing suspicion that the classical view of enzyme chemistry is somewhat oversimplified. The reactions produced by combinations of isolated enzymes do not in all respects duplicate those in the living cell. For instance, in the animal body the conversion of glycogen to glucose or of glucose to glycogen is profoundly affected by hormones such as adrenalin or insulin. But no one has succeeded in showing that the reconstructed process in the test tube is sensitive to the action of these hormones; in other words, it has yet to be demonstrated that insulin or adrenalin act on isolated enzymes. Nor has it been possible, by means of isolated enzymes, to duplicate the living cell's synthesis of such complex substances as proteins, phospholipins, sterols, porphyrins or fatty acids.

One could maintain that the failure to demonstrate hormonal effects or to accomplish complex synthetic processes in reconstructed systems is after all no reason to doubt that given time even these goals will be achieved by the methods of classical enzyme chemistry.

THERE have been other findings, however, that cannot be shrugged off quite as easily. These have to do with the behavior of certain complexes of enzymes that apparently can function only in teams. Thus David Keilin and his school at Cambridge University have for many years been studying a complex of enzymes obtained from heart muscle. This complex is found associated with large particles at least the size of an average bacterial cell. Many different enzymes are present in the complex, but no one of them can be readily separated from the rest. They are stuck together as in a mosaic. The unit is no longer the enzyme but a hierarchy of enzymes.

This complex of enzymes catalyzes the oxidation of a series of organic substances (substrates) by means of molecular oxygen. A substrate undergoing oxidation loses two electrons, the oxidizing agent gains two electrons. But the electrons are not transferred directly from the substrate to the oxidizing agent, they are handed from one to the other by an elaborate "bucket brigade." For example, the oxidation of malic acid (malate) by molecular oxygen is represented schematically by the following sequence, the arrows showing the direction of transfer of the electrons. malate→diphosphopyridine nucleotide→flavin dinucleotide→cytochromes→cytochrome oxidase→oxygen. Thus at least five separate transfer reactions are involved in this oxidation of malate as catalyzed by the Keilin complex of enzymes.

Innumerable attempts have been made to tear this complex apart and to reproduce in the test tube the individual events catalyzed by single enzymes, but success in that direction has been remarkably scanty. No one has yet been able to separate cytochrome oxidase from the cytochromes, or to isolate the individual members of the cytochrome group, with the single exception of a substance called cytochrome C. What is more, the few individual enzymes that have been isolated from the total complex do not show precisely the same properties in isolation as they did in the complex. For example, an enzyme called diaphorase, which catalyzes the oxidation of dihydropyridine nucleotide (one of the links in the electron transfer sequence), can use the cytochromes as oxidizing agents when in the complex but is unable to do so when separated from the complex.

These studies of Keilin have been followed by a whole series of similar reports by other workers. They have prepared from liver, kidney and other organs suspensions of large particles, like those reported by Keilin, that seem to play a part in the synthesis of various important biological compounds. The indications are strong that these units are not individual enzymes but teams of them, and that a complex is more than the simple summation of its individual members.

All this throws serious doubt on the view that the reactions produced in the test tube by combinations of isolated enzymes are the same as those that go on in the cell. Perhaps the most significant data bearing on this question is supplied by recent studies of the process by which sugar is burned to carbon dioxide and water in the body.

THE oxidation of glucose or sugar may be divided into two phases. In the first, glucose is fermented or split into two molecules of lactic acid. In the second, lactic acid is oxidized to carbon dioxide and water by the so-called citric-acid cycle discovered by H. A. Krebs of the University of Sheffield.

Properly speaking, the citric-acid cycle begins with pyruvic acid, which is formed from lactic acid by the loss of two electrons, accompanied by the loss of two hydrogen atoms: $CH_3CHOHCOOH$ minus two electrons yields $CH_3COCOOH$. The problem of the cell is to burn the latter compound, pyruvic acid, to carbon dioxide and water and thereby re-

lease energy for doing the work of the cell One could imagine a process whereby pyruvic acid was hacked down, carbon atom by carbon atom, until nothing was left but CO_2 and H_2O. The cell has preferred a more roundabout and elegant device for accomplishing the same result. Without plunging into the detailed chemistry of this process, we can extract its principle by picturing the fate of the carbon atoms. Let us strip pyruvic acid of all but its carbon atoms and represent it simply as c-c-c. Let us suppose that to start the cycle going there is available another substance with four carbon atoms. c-c-c-c.

The C_3 unit, pyruvic acid, combines with the C_4 unit, and the product is c-c-c-c-c-c-c, or C_7. Now C_7 is degraded, carbon atom by carbon atom, with a single atom burned off at each step, until it is reduced to the original C_4 unit. This in turn reacts with another C_3 unit, and so the process continues until all C_3 units are burned. The C splinter split off at each step is of course CO_2. This cyclical process has been called the citric-acid cycle because the C_6 stage was the clue to its discovery. We may accurately describe this system as a cellular furnace in which sugar (or rather the product of sugar fermentation) is burned to carbon dioxide and water.

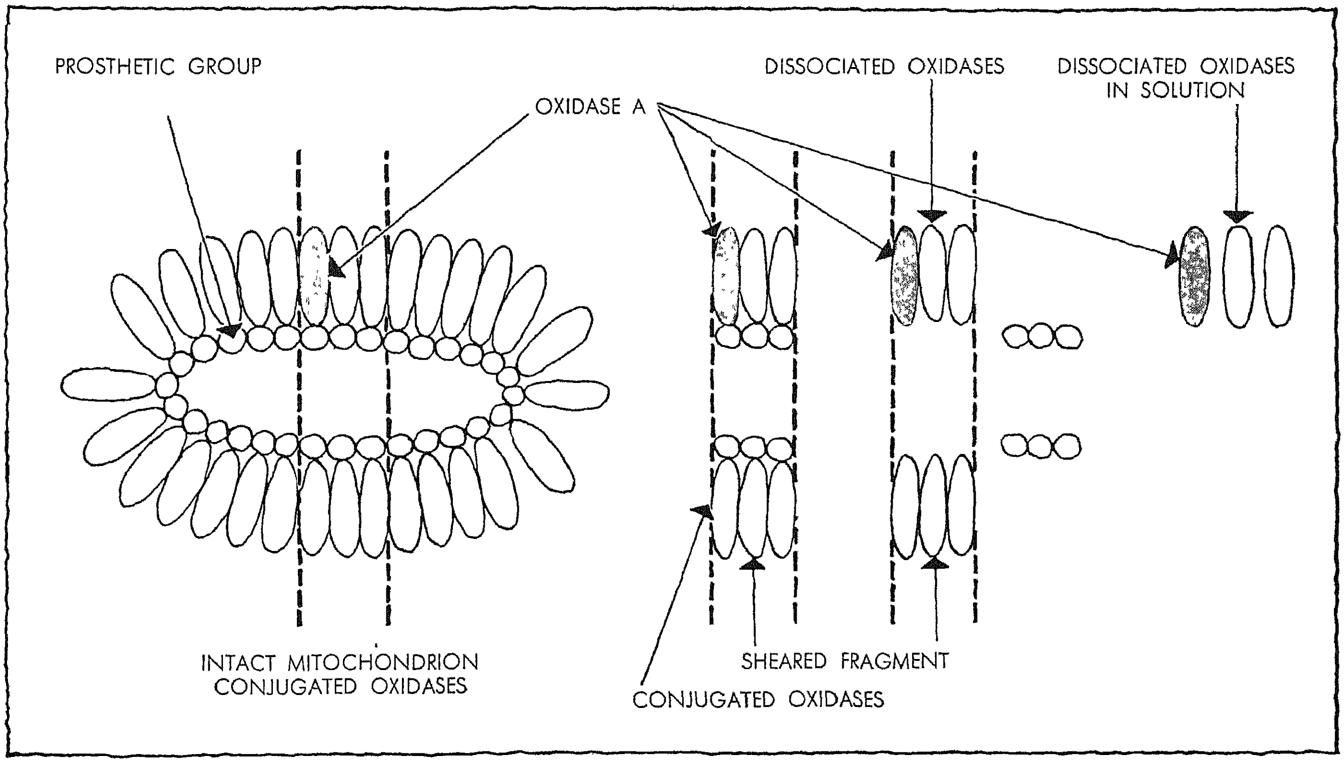
The cell does not have separate furnaces in which to burn sugar, fatty acids, amino acids and its other fuels. It makes one furnace do for all, in other words, it has adapted the citric-acid cycle most ingeniously for burning fatty acids and amino acids as well as sugar. The general scheme is pictured in the diagram of the citric-acid cycle which appears on page 50 This shows that the cycle has separate entrances for various substances, depending on the number of carbon atoms they possess. Every step in the cycle is like a door leading to the furnace. Sugar comes in at the C_3 door Fatty acids, with six carbon atoms, come in through the C_6 door; amino acids, varying in their carbon composition, enter through the C_3, C_4 and C_5 doors.

The oxidation of fatty acids actually proceeds in two distinct phases. For example, a fatty acid represented by c-c-c-c-c-c first is burned or broken down into c-c units. These c-c units correspond to acetic acid. Each of them can condense with c-c-c-c (oxaloacetic acid) to form c-c-c-c-c-c (citric acid), and so enter the furnace through the C_6 door. In a similar way amino acids are oxidized in one or more steps to form c-c-c (pyruvic acid), c-c-c-c (oxaloacetic acid) and c-c-c-c-c (α-ketoglutaric acid)—all of which are doors to the cellular furnace.

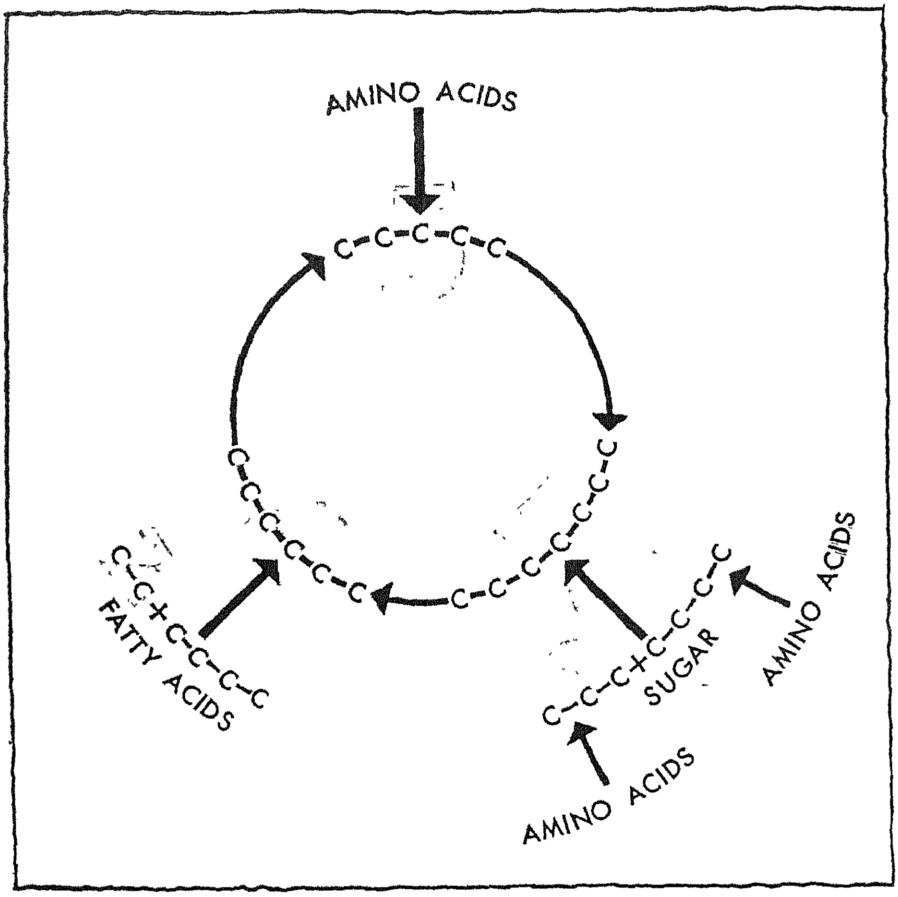
NOW all these events are brought about by a galaxy of enzymes which in honor of the citric-acid cycle has been named the cyclophorase complex. This enzyme system is present in every cell of the animal body. It is locked up in small bodies called mitochondria. Investigators have recently discovered that the mitochondria house all the principal oxidative enzymes of the animal cell. And the individual enzymes in the complex are handcuffed together, as it were, in the closest molecular juxtaposition. They can act only as a group.

Many other processes, oxidative and synthetic, go on in the cyclophorase complex But our concern here is to consider how the enzymes in the complex differ from their isolated counterparts. There is in the complex a variety of oxidizing enzyme known as the malic oxidase, which catalyzes the oxidation of the acid called L-malate to oxaloacetate. Malic oxidase consists of a protein to which is joined a "prosthetic group" (an enzyme auxiliary). It is possible to split off the prosthetic group from the protein. But once this is done they can never be joined again, at least so far as our present knowledge goes. We can restore some of the enzyme's catalytic activity by adding a large amount of the prosthetic group to the split enzyme, but the properties of this reconstituted enzyme are totally different from those of the original. For example, the split enzyme does not work maximally unless the malic acid that it oxidizes is present in relatively high concentration, whereas the original enzyme is fully active at vanishingly small concentrations of the acid. Furthermore, the split enzyme cannot oxidize the acid if even a trace of the product of oxidation is present, while the original enzyme is unaffected by the product of oxidation even in relatively enormous amounts.

The alteration of enzymes can be illustrated in another way. It is possible to transform the enzymes of the cyclophorase complex into the purely classi-



COMPLEX OF ENZYMES loses properties as it is broken down. Complex (*left*) oxidizes malic acid and converts phosphate into an ester. When split (*center*), it can oxidize malic acid but cannot convert phosphate. When further broken down (*right*), it cannot oxidize acid without large extra supply of prosthetic group.



CITRIC-ACID CYCLE is the mechanism of the cell for oxidizing lactic acid to carbon dioxide and water. It is also used to burn fatty acids and amino acids. Varieties of the latter may enter the cycle through three "doors."

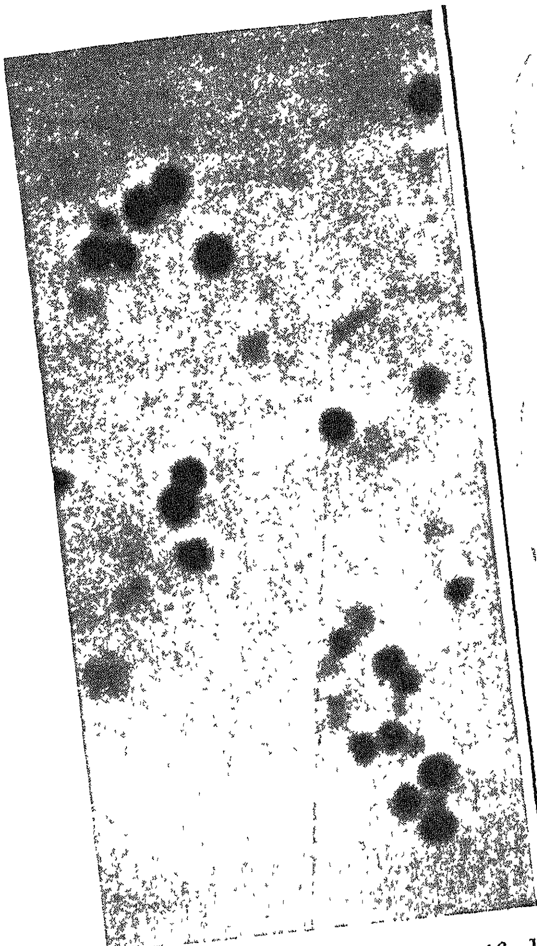
cal, isolated types by a series of mechanical and chemical steps. For example, in the mitochondrial body the intact cyclophorase complex not only oxidizes malic acid but converts inorganic phosphate into an ester—a process known as oxidative phosphorylation. Now if one splits the enzyme complex into fragments by some mechanical shearing device, similar to the blades of a high-speed cocktail shaker, this fragmented unit no longer is capable of oxidative phosphorylation. It has lost this property even though the malic oxidase is still intact and can continue to oxidize malic acid as before.

Now this disrupted unit in turn is exposed to acid under controlled conditions and the prosthetic group is split off. A whole new group of properties falls out in consequence of this second traumatic experience. Finally the split oxidase, which is still attached to particles, albeit much smaller than the original mitochondria, can be detached completely from the particles and brought into true solution. At that point, we have an isolated enzyme such as has hitherto been the chief subject of study in classical enzyme chemistry.

CLASSICAL enzyme chemistry has been concerned with the properties of the split oxidases. Its goal has been to isolate individual enzymes in pure form. In achieving this goal it has had to use methods which in effect tear the enzymes apart from their natural associations. It has proceeded on the tacit assumption that nothing is lost in the process. Apparently that assumption can no longer be regarded as safe. In the light of what has been learned about the transformation of the oxidases when they are isolated from the cyclophorase complex, it becomes evident that many of the enzymes on which classical enzyme chemistry has concentrated its attention are artifacts, and must be considered mere shadows of their former selves.

It would be unwise to discount completely studies of enzymes isolated by classical procedures. After all, the essential catalytic property of the oxidase is still retained; the nature of the prosthetic group has not been altered, and presumably many of the properties and characteristics of the protein have come through unaltered. The study of these classical oxidases can be of inestimable value to our understanding of the mechanisms of enzyme action. But in reconstructing the enzymatic events in the living cell we must consider not only the individual members of the complex but the chemical organization and structure of the complex as a whole.

The striking and inescapable fact is that once a complex is torn apart it is



MITOCHONDRIA, here magnified 1,500 times, are bodies inside the cell containing enzyme complexes.

in the same plight as Humpty Dumpty: all the King's horses and all the King's men cannot put it together again. Even if all the pieces are salvaged from the wreckage, they do not act together in the same way as the original complex; the chemical organization and structure of the whole is irrevocably lost. So the main task of enzyme chemistry in the future must be to learn what chemical principles underlie this organization and structure.

This kind of study may not be as esthetically satisfying as the isolation of single proteins in the form of beautiful crystals. But we shall have to come to grips with the "mess" if our goal is to understand the fundamental events of enzyme chemistry. The organic chemistry of sugars was a mess until the great German chemist Emil Fischer introduced new reagents which revolutionized this branch of structural chemistry. In spite of the recalcitrant complexity of our material, there is equal ground for hope that the application of new chemical techniques will resolve the problem of the organization of enzymes.

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The Plants of Krakatoa

When the volcanic island exploded in 1883, its life was completely extinguished. Botanists have since observed a unique natural experiment in the propagation of plants

by F. W. Went

At two minutes past 10 on the morning of August 27, 1883, one of the most violent explosions ever experienced by man occurred on an island between Java and Sumatra in the East Indies. Although the nearest inhabited place was at least 25 miles distant, 36,417 persons in the region were killed, mainly by drowning in the tidal wave that followed the explosion. The blast was heard more than 1,000 miles away.

The source of this awesome detonation was the blowing up of the central part of Krakatoa, a volcanic island which had had a long history of disquietude. The island had begun to disintegrate several hours before the main explosion, and a series of pulverizing eruptions continued throughout the day. When men first dared to approach the island two months later, a sea 800 feet deep covered the major part of the island, where the volcanoes Perbuatan and Danan had once stood. Approximately six cubic miles of rock and pumice had been blown into the air! (This gives us a better perspective for judging man's relatively puny accomplishments with dynamite and uranium.)

All that was left of Krakatoa was a ragged, 2,500-foot peak. It was completely covered with a thick layer of smoking pumice and ashes, still too hot to walk on with bare feet. Clouds of steam rose from many parts of the island, especially from the gullies that rainwater had scoured in the loose pumice. All animal life, of course, had been wiped out. Not a tree, shrub or other plant survived.

A place so utterly desolate and devoid of life would hardly seem a promising site for an investigation of how plants and animals become distributed over the earth. When one gives the matter a little thought, however, he can see that such a sterilized island offers a marvelous opportunity for just such a study. To resettle sterile Krakatoa Island, all seeds, spores and animals had to cross a 25-mile stretch of sea. There was an island closer than this, Sebesi, about 12 miles north of Krakatoa, but most life on Sebesi had been destroyed by toxic gases and a thick layer of ash, and it was hardly a source of seeds or spores.

In May, 1884, nine months after the eruption, the French botanist E. Cotteau visited Krakatoa. He reported: "In spite of all my investigations, I was unable to observe any trace of animal or plant life with the exception of a single spider; this hardy pioneer of resettlement was busy spinning its web."

Three years after the eruption, a party led by the Dutch botanist Melchior Treub found a very different situation. On the beach were growing many of the plants commonly found along tropical seashores. Farther inland Treub found many ferns and some grasses, but very few other plants.

Unfortunately it was another 10 years before the island was revisited by botanists. By then it was fairly well covered with green: here and there stood groves of Casuarina (the horsetail tree), and there was a wide scattering of wild sugar cane. Four species of soil-inhabiting orchids were found. On the shores grew young coconut trees. In general, vegetation was much more abundant on the shores than in the interior.

It was not until 1906 that the island was densely covered with plants. The vegetation was then mostly grass with some trees here and there. By 1920 trees had taken over perhaps half of the surface, and in 1930 the whole island was again covered with a dense, though low and young, forest.

What does all this mean in explaining the natural distribution of plants over the world?

Since the vegetation of Krakatoa had been so completely destroyed, new plants could develop only from seeds and spores that were somehow transported to the island from other places. How might they have been carried?

In the first place there is the wind. Very light spores or seeds can be carried by even gentle air currents. Bacteria, for instance, are floating everywhere in the air, even in a perfectly quiet room. Spores of ferns are no heavier than pollen grains, which are commonly moved by a breeze from pine tree to pine tree to cause pollination. It is significant that almost half of the plants observed on Krakatoa three years after the eruption were ferns, whereas ordinarily ferns constitute no more than 10 to 20 per cent of a stable tropical vegetation. The ferns' mode of distribution by means of very light spores gave them an advantage over most other plants. In later years plants with heavier seeds caught up, but in the beginning the ferns were the most numerous settlers.

Orchid seeds are almost as light as fern spores: there are many millions of them in an ounce. Most orchids require trees to grow on, or at least rich humus in the soil, yet in spite of the handicap of poor soil and treelessness on Krakatoa, 13 years after the eruption four species of orchid were flowering there, which shows that great numbers of orchid seeds must have been blown to the island.

Even heavier seeds can be carried by wind, especially when they are provided with hairs, such as those of cotton, cottonwood and dandelions, or with wings, as in elm fruits. Some of the first grasses found after the eruption undoubtedly also arrived on the wings of the wind. It is estimated that about 40 per cent of all species of plants now living on Krakatoa arrived there by this means. Thus the wind must be considered the most effective and important agent in dispersal of these tropical plants.

The seeds of certain other plants on Krakatoa, such as the coconut palm found flowering on its shores in 1896, are too heavy to be carried by wind. The big coconuts from which these trees sprang must have been brought by the sea. Coconut palms grow along the shores of all tropical islands in the Pacific and Indian Oceans. Under natural conditions they do not extend far inland. When the coconuts drop off, many get washed away by the sea. They remain afloat, and near tropical shores one can occasionally see a coconut bobbing up and down on the waves among logs and other flotsam. The fruits and seeds of most other tropical shore plants are

similarly carried by sea currents over long distances. Experiments have shown that floating for several weeks in sea water does not injure them. They will germinate as soon as they are washed ashore and watered by rain water. A hard seed coat or a protective cover of strong fibers protects the seeds from injury when they scrape over the sand.

THIS natural experiment on Krakatoa explains why the coastal vegetation of all the Pacific islands is so uniform. The several dozen varieties of plants found on their shores have been distributed from island to island by the ocean currents. This method of distribution of seeds is so effective that even newly formed islands with no other flora are soon colonized by beach plants. Indeed, ocean transportation explains a striking phenomenon of the distribution of plants on great continents. Ordinarily we think of plants as spreading over land and being halted by oceans. But in Africa the beach flora of the continent's west coast is very different from that of the east coast. The former is like that of the east coast of South America, thousands of miles away across the South Atlantic, while the latter is like that of the islands of the Indian Ocean and the Pacific. The explanation is that the beach plants do not spread inland across the continent; they can travel only across the sea. Thus the varieties of shore vegetation, unlike most other plants, range around ocean basins instead of within continents.

In 1886 only plants distributed by wind and sea currents were found on Krakatoa. By 1896, however, some 9 per cent of Krakatoa's vegetation had arrived by other means, and today about 40 per cent of all its species have done so. In most of these cases it is very likely that the seeds were distributed by animals, usually by birds but occasionally by man.

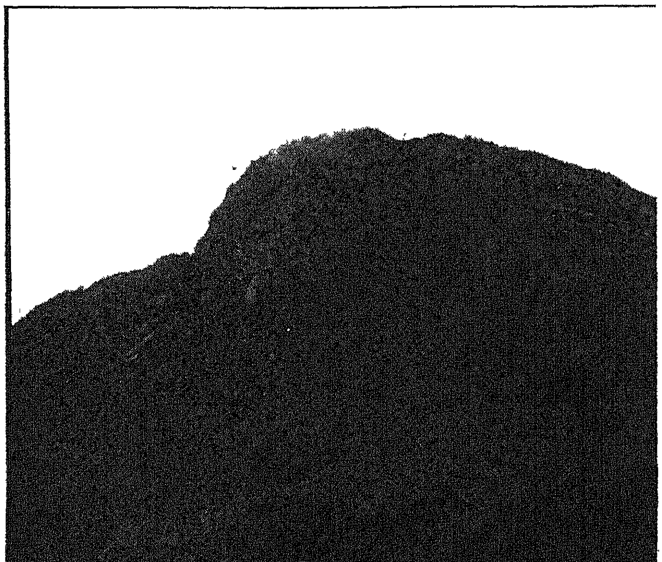
In 1916 several men settled on Krakatoa to exploit the pumice. They brought with them certain fruit trees, such as mangoes. These survived only a few years. After the settlers had left, they were engulfed and obliterated by the dense jungle Evidently our cultivated plants can survive only if helped by man in their struggle for existence We know by experience how seldom a corn or tomato plant that escapes cultivation becomes established among the wild vegetation.

The majority of plants distributed by animals must have been brought to Krakatoa by birds. The occurrence of so many plants with fairly large seeds that could not have arrived by wind or water, and the fact that most of these plants have fleshy fruits that are eaten by birds, makes this almost a certainty. The seeds of many fruits which birds eat are not destroyed in their digestive tract, but are still intact and viable in their droppings. Thus any seeds remaining in the digestive tract of a bird that had flown across the 25 miles of sea between Java and Krakatoa would have a chance of germinating in its droppings. Among the plants presumably transported to Krakatoa by birds belong figs and papayas.

One might object that mistletoes, which are spread exclusively by birds, do not occur on Krakatoa as yet, though they are very abundant on the nearby islands. Observations have shown, however, that mistletoe seeds are spread almost exclusively by species of Dicaeum birds. These birds retain the seeds for no more than 12 to 20 minutes after ingestion, and therefore could not have carried them over a distance of 25 miles, which would require at least an hour's flight. Other birds, such as the tjalak, which is common in Java, can retain seeds in their intestines for at least 100 minutes, they do not eat mistletoe fruits, however, and therefore could only have transported other plants.

It is certain that birds can carry seeds for fairly long distances, but in the absence of evidence of any method of transport except in the food they have eaten, such dispersal is definitely limited by the length of time the birds hold their bowel contents. Charles Darwin believed, and in one case actually proved, that seeds could be distributed by sticking to mud on the legs of wading birds. This would explain the long-distance transportation of marsh plants, but there are no marshes on Krakatoa It is of course possible that seeds may become attached to birds by some other means, but that is very hypothetical.

ANOTHER mechanism often invoked to explain the spread of plants is the attachment of seeds to floating logs, which may drift for great distances in sea currents. This is a very unsatisfactory hypothesis, because most seeds cannot stand contact with sea water. Besides, only a certain few plants can germinate and grow on beaches, or as far inland as



STEEP CLIFF is a fragment of Krakatoa's former crater. The volcano lies midway between Java and Sumatra. When it exploded, 36,000 people died. Two months later clouds of steam still rose from its sterile rocks.

LUSH GROWTH now covers Krakatoa. Three years after the explosion, beach plants were found along its shores. Inland were ferns and grasses. Since then other waves of plants have become established and competed.

floating logs are washed. Yet this mechanism should not be entirely discarded. For example, I found two lizard eggs, which seemed viable, hidden in a cavity of a floating log that had been washed ashore on Krakatoa.

No matter whether we can agree in each case on how a certain plant reached Krakatoa, the important fact remains that all these plants arrived there by one means or another—this is the most significant result of the large-scale natural experiment initiated by the volcanic explosions on the island. One might assume, of course, that seeds of most of the plants later found there had survived August 27, 1883. One botanist has taken this stand, and has written a whole book to prove his contention. However, he has failed to convince other botanists that plants, seeds, roots or rhizomes were able to withstand fires, toxic gases and terrific explosions, and later a cover of hot ashes and pumice 20 to 200 feet deep that charred everything it touched. Two months after the eruption the whole island still steamed after a rain, indicating that temperatures near the boiling point still existed deep in the pumice.

The biology of Krakatoa is full of interesting problems No stability has yet developed in its plant or animal life. For instance, some years the island may be overrun by rats, yet a year or two later the natural equilibrium will swing back to the point where hardly a rat can be found. Here is a typical example of a biological problem which was highlighted by the Krakatoa experiment. In the Asiatic tropics are many so-called ant plants in which ants have a permanent abode. The curious fact is that each kind of ant plant has its own kind of ant. Thus an epiphytic fern, *Polypodium sinuosum*, grows in Java on the branches of trees, and in its hollow rhizomes nests an ant called *Iridomyrmex myrmecodiae*. By one of the chances of distribution, this ant arrived on Krakatoa by itself before the fern had settled there. According to the biologist who first found the ants, they were running around nervously, obviously lost. When I visited Krakatoa several years later, I found the fern growing on branches of trees—and *Iridomyrmex* had settled in its rhizomes. The fern could only have been distributed in its spore form by the wind, otherwise it could not have started to grow on tree branches. The ant *Iridomyrmex* had lived on Krakatoa, alone and obviously unhappy, for many generations; the moment its symbiotic partner arrived, the old symbiosis, so rudely interrupted by the chances of dispersal, was re-established. This certainly is a most interesting example of instinct and the tenacity of characters of adaptation.

KRAKATOA is, of course, a limited experiment. In evolutionary botany we want to explain the distribution of plants over much greater distances, not 25 miles as at Krakatoa, but 250 miles, 2,500 or even farther. If Krakatoa, however, had been located at such a distance from the nearest vegetation, it would have taken too long for seeds to arrive there; it might have been thousands of years before an appreciable number of plants settled and made a new vegetation cover.

Under most natural conditions, we actually have to count in millions of years when explaining the distribution of plants. Let us take another example from Java and Sumatra. Although these islands are fairly old in a geological sense, they did not have any high mountains until volcanoes developed on them. These volcanoes are of quite recent origin, not more than a few million years old. They reach up to almost alpine altitudes, and none of the typical lowland tropical plants can grow on their tops. On the other hand, most of the kinds of plants growing on their tops cannot possibly grow in the steaming lowlands. At high altitudes on these volcanoes we find buttercups, gentians, brambles and blueberries, which are never found at sea level in the tropics. They must have spread from volcano to volcano, and they must have done this during the last million years or so. Many of these volcano-hopping plants have edible fruits, and thus have a good chance to be spread by birds. But not all the volcanoes have all the plants growing on them that their climate and soil will allow This shows that a million years is not quite long enough for chance to distribute seeds thoroughly over distances of up to 1,000 miles. Another case in point is the plant *Primula prolifera,* which originated in the Himalayas. It is now found on a few volcanoes in Sumatra—a distance of about 1,500 miles from its place of origin. In Java, 500 to 1,000 miles farther on, this plant is found on only three volcanoes, although about 20 are high enough for it to grow on. We see here that *Primula* has not only hopped from volcano to volcano, but has skipped them as well.

There have been other terrific volcanic eruptions, which sterilized hundreds of square miles. The explosion in Alaska in 1912 of Mount Katmai, which disappeared and left only the "Valley of Ten Thousand Smokes," annihilated the vegetation over a wide radius. Katmai was on the mainland, however, and vegetation was able to infiltrate the sterilized area slowly from undamaged areas farther away. Thus not much could be concluded from it about the mode of distribution of plants. The Krakatoa experiment still stands as the most instructive in history.

F. W. Went is professor of plant physiology in the Kerckhoff Biological Laboratories of the California Institute of Technology.

What GENERAL ELECTRIC People Are Saying

P. C. BOGIAGES

General Engineering & Consulting Laboratory

AIRCRAFT ELECTRICITY: The advent of World War I brought definite demands for auxiliary power in aircraft. Its main purpose was to supply radio and instruments. Experience gained by the automotive industry with the 6-volt system was utilized to adapt it to aircraft service, using an 8-volt charging generator. About 1925 use of a 12-volt system, originally developed for truck service, was inaugurated...

The trend toward very large multiengined planes began in 1939... It soon became apparent that the 12-volt system was inadequate to supply the additional loads essential to flight in these craft... A lighter, more efficient 24-volt system was the outgrowth of these difficulties...

Experience with the 24-volt system led to the development of the 120-volt system, for which great expectations are held. This system is particularly applicable to large aircraft and may well become universally accepted as the standard d-c system of the future.

General Electric Review, July, 1949

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NEIL BURGESS
J. C. BUECHEL

Apparatus Department

THRUST OF TURBOJETS: The thrust available at low airspeeds in turbojet-powered aircraft is substantially less than in propeller-driven aircraft. For example, a turbojet developing a sea-level static thrust of 5000 pounds delivers a net airplane thrust-horsepower of approximately 6000 at an airspeed of 400 knots. An engine of this power driving a propeller would develop substantially more static thrust for takeoff use. In addition, since the turbojet is substantially more sensitive to changes in ambient pressure and temperature, the problem may be more aggravated in hot weather or at airports located several thousand feet above sea level...

On the basis of our investigations it is concluded that thrust augmentation can be successfully applied to the turbojet engine by water injection or by exhaust reheat. Each type of augmentation appears to have definite advantages in certain aircraft applications.

Combustion-chamber water injection can be added to the basic engine with no measurable loss in the performance of the engine and at an increase in weight of about 1 per cent. The maximum amount of augmentation is approximately 18 per cent under the sea-level static condition and is obtained with the expenditure of approximately 25 pounds of injection fluid per hour per pound of additional thrust.

Use of an exhaust reheat burner will increase engine thrust by approximately 40 per cent under the sea-level static condition, and by substantially higher percentages under flight conditions, at the expense of about 12 to 15 per cent increase in engine weight. Each pound of additional thrust obtained with exhaust reheat is obtained with the expenditure of approximately six pounds of additional fuel per hour. When operating as a normal turbojet engine, the reheat engine suffers a loss in performance of about 3 to 5 per cent as a result of exhaust system losses. The type of augmentation is, however, well suited to the requirements of interceptor aircraft requiring large amounts of additional thrust at the expense of substantial increases in fuel consumption.

Institute of Aeronautical Sciences, Royal Aeronautical Society, May 24, 1949

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F. P. WILSON, Jr.

Apparatus Department

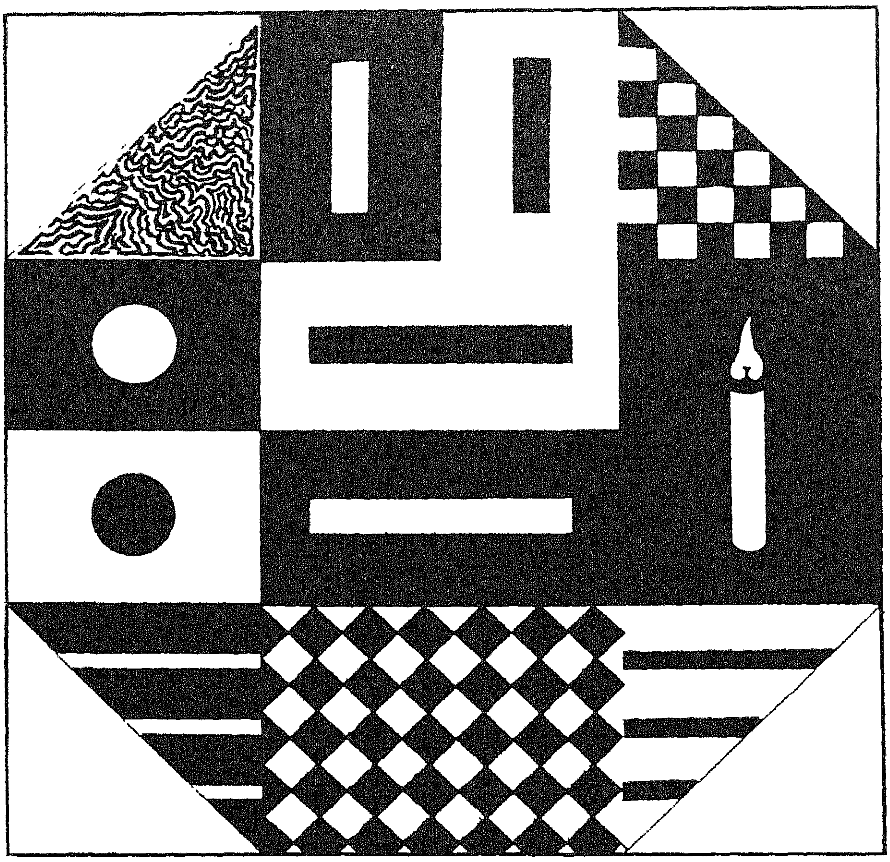
MATERIALS AND PROCESSES: The layman can hardly appreciate the extent to which materials and processes control and limit the development, design, and manufacture of electrical apparatus. Only by continual development of new and better materials, and by processing them ever more precisely and economically is it possible to continue producing "more goods for more people at less cost." For example, the life of a turbine is limited by the creep of an alloy steel, the safety of a ship may depend on the fatigue strength of a highly stressed gear, and the quality of the electric refrigerator requires the most exacting chemical control of the materials sealed into it for life.

These requirements, which become more pronounced with the improved performance of established products and the ever-growing variety of new products, constitute a challenge to the chemist, chemical engineer, metallurgist, physicist, and other scientists who can contribute in the field of materials and processes.

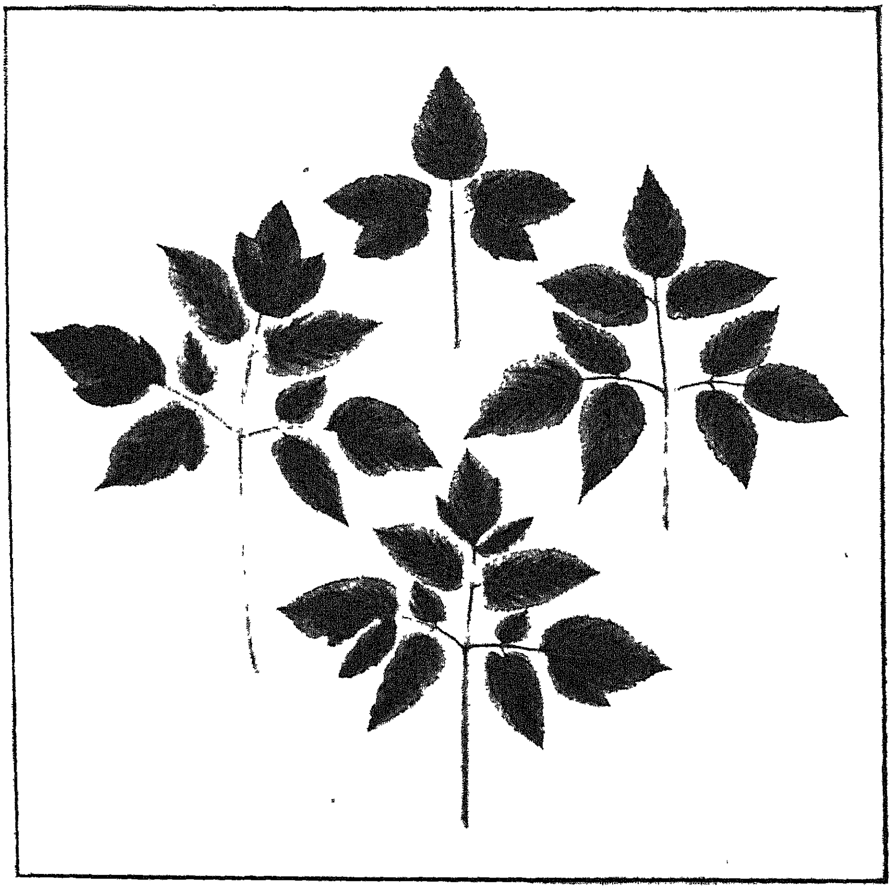
Chemistry provided the film on Formex wire, which, because of its toughness, permitted the elimination of cotton covering. This reduced the space required in coil windings and eliminated 6,000,000 lb of structural materials per year in apparatus because of reduced size. This saving in space has also permitted the design of equipment to meet exacting requirements which otherwise would have been impossible.

Tungsten carbide led to the formation of a new company. Alkyd resins set the stage years ago for the growth of what is now the Chemical Department. Askarel revolutionized capacitor design; improved silicon steel reduced the size and cost of transformers; high-temperature alloys permit higher temperatures in steam-turbine operation and made the gas turbine possible; improved lubricants, new finishes, and synthetic insulation are only a few examples of laboratory activity in the materials field.

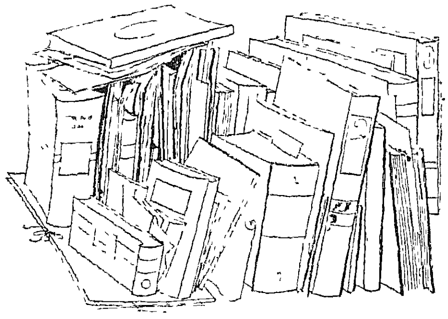
General Electric Review, July, 1949



COLOR was discussed by Goethe in *Farbenlehre* (color theory). This illustration, from 1842 edition of book, set forth some of his ideas on contrast.



PLANTS were explained in *Die Metamorphose der Pflanzen* (the metamorphosis of plants). Goethe thought fruits and nuts were variants of "ideal leaf."



by James R. Newman

GOETHE ON NATURE AND SCIENCE, by Sir Charles Sherrington. Cambridge University Press (75 cents)

AMONG the lectures and miscellaneous writings celebrating the bicentenary of Goethe's birth it is puzzling to find tribute to the great man's scientific achievements. Sir Charles Sherrington's essay (first issued in 1942 and now reprinted with major additions and revisions) will not, I trust, strike a sour note amidst these international jubilations, though it provides a fairly judged corrective to lingering misconceptions. For, as Sherrington makes clear, whatever else Goethe may have been he was not a scientist. Indeed, in this department of knowledge, as everyone not overcome with hero-worship could by now have ascertained for himself, Goethe was a magniloquent and befuddled bore. His scientific work is an assortment of erroneous conjectures, in part based on superficial experiments, given to the world with Olympian self-assurance and accompanied, in the most important case, by silly attacks on Sir Isaac Newton. The story is easily documented

"I do not attach importance to my work as a poet, but I do claim to be alone in my time in apprehending the truth about color" Thus wrote Goethe to the faithful and indestructible Eckermann. (Among all the creatures of earth, perhaps the most remarkable are the few Boswells and Eckermanns, content to endure what must be endured in recording the unabridged utterances of gabby old men growing gabbier as they grow older.) What was the "truth about color," as held by Goethe? From Buttner, the botanist, he borrowed some prisms to perform the classical experiments of Newton. The famous *Opticks* which appeared in 1704 had shown that white light was composed of colored lights. This fact Goethe laudably set out to prove for himself. "One look through a prism," writes Sherrington, convinced *him that Newton was a fool.* "To his amazement the white wall at which he gazed through the prism remained white. Color showed only where something dark edged the white. Color showed brightest of all on the window frames"

The experiment, trivial as it was, impelled Goethe further to develop and to

BOOKS

Was Goethe a scientist? Hero worship has obscured the fact that he was not

spread his own theories in print. (Blessed with good health and immense energy, he was always ready, when thus inspired, to launch into song, poetry or prose.) His main scientific labor, highly praised among those who have not troubled to read it and/or know even less than he did about optics, was a large book on the theory of color (*Farbenlehre*). As a supplemental effort he published a sketch maligning Newton and ventured a number of satirical verses (*Katzenpasteten*, *i.e.*, "cat-pies") with Newton as their butt.

The prism, he thought, implied a "naive attempt" to analyze not color but light. Light cannot be analyzed, he said, because it is "an elemental entity, an inscrutable attribute of creation, an 'Einziges' [an 'only'] which has to be taken for granted." And the manner of Newton's attempt! "Through a tiny hole to admit a poverty-stricken thread of light into a darkened room [Sherrington's paraphrase], when by going into the open day any amount of it could be had—no wonder the students laughed and ran off!"

In place of this "physicist's mathematics"—the phrase epitomized his contempt—Goethe advanced opinions based on the optics of Aristotle and his pupil Theophrastus—physicists whose views were somewhat outmoded by the 18th century though Goethe appeared to be unaware of it. The prism, he asserted, merely introduced hundreds of complications and "dragged in mathematics unwantedly." It "perpetrated an experimental incoherence." Light must be regarded as an *Urphanomen* (ground-phenomenon), it is "self-explanatory" and cannot be further decomposed, the color effects of a prism, or wherever else observed, are due to the "cloudiness" or other attributes of the medium that is interposed between the source and the eye.

The *Farbenlehre* offers an admirable example of pomposity in defending the concept of *Urphanomen:* "Faithful observers of Nature, even if in other things they think very differently, nevertheless agree together that all which appears, everything that we meet as a phenomenon, must be either an original division which is capable of union, or an original unit which can be split and in that manner exhibit itself. To sever the conjoined, to unite the severed, that is the life of Nature; that is the eternal drawing together and relaxing, the eternal syncrisis and diacrisis, the taking in and the pouring out of breath of the world in which we live, and move and are."

As for this "faithful observer of Nature," he pontificated not only that colored light was impossible, but that "turbidity . . . is the initial rudiment whence is developed the whole science of chromatics" The moral of Wordsworth's famous line, "To the solid ground of nature trusts the Mind that builds for aye," commended itself to Goethe, yet he permitted neither mathematics, nor apparatus, nor, indeed, patient observation itself to interfere with his intuition. One infers that when he studied nature he was less concerned with what it had to tell him than with the imaginings that filled his mind as a result of what he saw. Except for certain conclusions on the principles of contrasting colors—conclusions confirmed by Sherrington's own investigations—Goethe's theories of light and color can hardly be taken seriously. If Goethe's descriptions, said Helmholtz, are intended as physical ". . . [they make] no sense. . . . [They must be understood] only as figurative dramatizations of the process." A tactful defense.

One of Goethe's difficulties, writes Sherrington, was the "predominance of the visual in him" He understood what could be pictured, or rather what *he* was able to picture. Abstractions, at least in relation to Nature, were abhorrent. The interest of which he never wearied was in "the shapes assumed by life," both plant and animal. He preferred, while at school, the company of anatomy students over law students—an understandable preference in any case, he "frequented the dissections"; he collected plant specimens and attempted, not too successfully, to memorize the names of the Linnaean system. But his original contributions to the study, apart from giving it the name morphology, by which it is now known, were worth little more than his theory of color. In regard to leaves, for example, it came to him that "Nature kept in mind an 'ideal' leaf." All leaves of whatever kind were variants of this "ideal": petals, sepals, stamens, the shell of the nut, the flesh of the apple were merely "modifications" of the leaf. This was another theory which unfortunately turned out to be false.

In studying animal forms he drew the conclusion that "the skull itself is vertebrae continuing those of the backbone." Here, he thought, Nature, in creating backboned animals, strove for an "ideal vertebra." "How far," he exclaimed, "from the tortoise to the elephant, and

yet the gap is bridged entirely by intermediate forms! Because the whole series belongs to one ideal type" Later anatomical researches showed Goethe's view to be incorrect.

He invented a "law" of the "correlation of parts" It stated that the "long body of the snake is obtained by depriving the creature of limbs", that the frog got its long legs at the expense of shortening the body. In other words, as Sherrington paraphrases the law, "nothing new could be added to an animal-shape except at the cost of taking something away." Goethe was so pleased with his discovery that he wrote a poem about it The "law" was another bad guess.

This was the sum of Goethe's science. Some nonsense about color, a false conjecture about leaves, another about the skull; a law of correlation which Sherrington labels "a clumsy error." Yet one hears it said that Goethe was an accomplished scientist, a universal genius who created much in this field and might have created more had there been fewer demands on his time.

Sherrington points out that Goethe possessed neither the temperament nor the disinterestedness necessary to a scientist. He was a poet, a pantheist and an enthusiastic observer of nature—an observer, that is, where no tiresomely complicated instruments or calculations were required. The least datum might serve him as a basis for a grandiose system. He had neither the patience nor the humility to reflect, to add fact to fact. On discovering some new point—new to him—his first inclination, and often his last, was to leap to a theory and to break into verse. There is no reason to believe that he had a remote inkling of the concept of evolution, though admirers, straining the words of some poem or apothegm, have called him Darwin's precursor. He had no notion of heredity but instead accepted "nurture" as the determining influence in natural change. He could not tell a lark from a sparrow; he was a lover but not a knower of nature.

Throughout his life Goethe was a staunch conservative, a friend, in his own words, of the "established order"; an enemy of skepticism and equality alike. This conservatism found expression in his literary works and, one may suppose, in his scientific beliefs. I have noted that Aristotle's methods served him for both inspiration and model. Examine the implications of this conservatism and you will discover, I believe, an important clue to his lack of success in science. What I mean is this The phrase "science moves forward" is, in a sense, misleading. Fundamental discoveries are not so much a "moving forward" as a destroying of older theories and the replacement of them by newer and better ones. In this game the cautious, conservative player usually comes off poorly. One may reason that Goethe was more inhibited as a scientist by rigidity of outlook than by inadequate training in physics, botany and zoology. It is surprising to learn how often men schooled primarily in one field have been able to enrich another· "It is no accident [I quote from C. D. Darlington's Conway Memorial Lecture] that bacteria were first understood by a canal engineer, that oxygen was isolated by a Unitarian minister, that the theory of infection was established by a chemist, the theory of heredity by a monastic schoolteacher, and the theory of evolution by a man who was unfitted to be a university instructor in either botany or zoology" As a lawyer, government official, theatre director, painter, poet and novelist, Goethe gave sufficient evidence of versatility so that it was not beyond expectation that his passionate love of nature and professed love of science would issue in creative achievements.

Yet it came about that, living at a time when Boyle had founded modern chemistry and Lavoisier, Cavendish and Dalton "had established it"; when Newton's vast discoveries had led Lagrange and Laplace to further great achievements; when the physical, biological and mathematical sciences were in a state of ferment and unparalleled growth, he "lay becalmed, so to say, in a small quasi-scientific backwater." In almost every respect, Goethe's thinking was remote from the positions science had already reached. The names he used, the qualities he ascribed to natural forces "were shot through with anthropomorphism, which, unless used purely as metaphor, *is* the occult." In his scientific judgments we are back, says Sherrington, in the "mediaevum and early renaissance."

Scientific progress rests on measurement and number, on patient watching and testing, it depends also upon a special sort of insight and imagination regarding the crucial things of the physical world, the things to be singled out as significant from a multiplicity of phenomena. Goethe was neither disposed to submit to science's discipline nor so divinely gifted that he could afford to disregard it. If anything, the imaginative powers that served him in literature betrayed him in scientific thought; perhaps one should go further to ask whether his literary works are not marked by the traits which handicapped him in science.

It remains to add that no living man is better qualified than Sir Charles Sherrington to appraise Goethe on nature and science. A giant among scientists, a philosopher, a distinguished literary figure, an old man, wise, sympathetic, unsentimental and unafraid, Sherrington embodies the virtues and talents so often ascribed to Goethe himself.

ANIMAL ENCYCLOPAEDIA: MAMMALS, by Leo Wender. Oxford University Press ($4.50). From Aardvarks to

Zwart-wit-pens, a handy dictionary of 1,500 mammals, giving for each species facts about height, weight, color, habitat, and occasional curiosa The Romans fattened and ate the Fat Dormouse, the Coypu, whose coat gives "nutria," is reared on fur farms "from which it frequently escapes", the House Rat is arboreal, entering buildings by roofs and windows, while the Brown Rat is a burrower and swimmer, coming in through the drains; there are common, notch-eared, leaf-nosed, epauletted, hairy-armed and hair-footed bats There is also a Sombre Wallaby. The illustrations and reproduction, however, leave something to be desired.

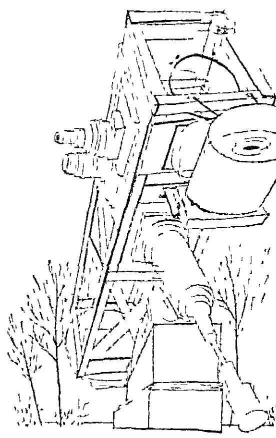
STUDIES IN PHILOSOPHY AND SCIENCE, by Morris R. Cohen. Henry Holt & Company ($4.50). A collection of scattered articles and book reviews gathered from the writings of the noted philosopher who died in 1947. It includes his sharp critique of Francis Bacon and the inductive method, the celebrated exposition of the theory of relativity written for *The New Republic* in 1920, *The Faith of a Logician,* and a number of essays on John Dewey, Hegel, Benedetto Croce and Josiah Royce. Professor Cohen wrote with clarity, force and wit, and even these essentially minor pieces show the range and grasp of a distinguished intellect, of a widely honored and beloved teacher who deeply influenced, in their formative period, a number of the leading contemporary American philosophers.

JANE'S ALL THE WORLD'S AIRCRAFT, 1948. The Macmillan Company ($20.00). This new edition of *Jane's Fighting Ships'* younger cousin maintains the high standards of earlier years in the face of mounting difficulties due to the rapid congealing of all channels of military information. The air ministries and departments of the world are more on the defensive and thus even touchier on the subject of security than the various armies and navies. The illustrated record of U. S and British aircraft production during the last year constitutes two thirds of the book. The diversity and preponderance of military aircraft are astonishing, the most unlikely monster designed to gratify unfriendly impulses being Northrop Aircraft's Flying Wing. "Russia," as Leonard Bridgman, the editor, remarks in the preface, "remains an enigma." The Red Air Force section has been entirely revised, now occupying 14 pages (instead of only six pages, as last year); but the jet-propelled Ilyushin and Tupolev bombers, the Mig (Mikoyan and Gurevich) jet fighter, the new Yak 15 turbojet–the newest models and types, in other words–are not displayed by means of photographs but rather as artists' sketches prepared on the basis of information obtained "from ciné film exposed from the ground through a telescopic lens" at the 1947 Aviation Day display in Moscow

CHRISTIAN HUYGENS AND THE DEVELOPMENT OF SCIENCE IN THE SEVENTEENTH CENTURY, by A E. Bell. Longmans, Green and Company ($4.50) A clear, readable account of the life and work of one of the foremost scientists of the 17th century. Huygens has to his credit the first accurate pendulum clock, a geometrical treatment of the reflection and refraction of light, a considerable extension of the science of mechanics including the first satisfactory formulation of the nature of centrifugal forces, major improvements in the telescope and the discovery of the rings of Saturn. He was not, however, as is often stated, a proponent of the modern wave theory of light, although he did suggest a "pulse theory." Dr. Bell's book is divided into two parts, biographical and scientific, a plan not without its disadvantages. The book serves a useful purpose for the general reader, there being no other modern or English biography of this pioneer scientist whom Newton, not given to extravagant tribute, praised as "the most elegant mathematical writer of modern times, and the most just imitator of the ancients. . . ."

UNRESTING CELLS, by Ralph W. Gerard. Harper and Brothers ($4.00). In the past few decades physicists have made a number of ambitious attempts to explain physics to the educated layman. Similar writing by biologists has usually been limited to smaller segments of biology, doubtless because of the greater specialization of the biological sciences. *Unresting Cells* is a notable exception. The author, professor of physiology at the University of Chicago, has covered a wide range of such subjects as metabolism, enzymes, growth, reproduction, differentiation and heredity in a literate and detailed way. The book was first published nine years ago, but was quickly out of print because of wartime restrictions. It has now been reprinted.

ACETYLENE CHEMISTRY, by Julius Walter Reppe. Charles A. Meyer & Co., Inc. ($10.00). During the war J. Walter Reppe, head of I. G. Farben's main research laboratories, became something of a legend among the world's chemists. The Germans wanted to build a chemical industry that was independent of their scarce supplies of oil and grain, so Reppe and his men devised remarkable processes utilizing the dangerously reactive gas acetylene, which can be made from coal [SCIENTIFIC AMERICAN, January]. At the end of the war Reppe was interned in "Camp Dustbin" and put to work writing his chemical memoirs. The present volume is a translation of the highly technical but historically important result.



THE AMATEUR

Conducted by Albert G. Ingalls

JOHNSONIAN is the name suggested by this writer for a new type of Gregorian telescope devised by Lyle T. Johnson, a physicist amateur astronomer of La Plata, Md. Johnson gave much thought to the evil effects of the conventional secondary mirrors that are used in compound telescopes, and that are best adapted to observing the planets because they magnify highly. These secondary mirrors lie squarely in the path of the incoming light. Not only do they cut off some of it, but they cause a bending of the rays that graze their edges. This diffraction renders the images less distinct and reduces planetary contrast.

Seeking ways to reduce this obstruction, Johnson proposed to take the secondary mirror entirely outside of the tube, and leave in its place only a tiny diagonal flat mirror to reflect the rays to this secondary. His final arrangement is shown in the drawing on page 63, where it will be seen that only one off-axis side of the secondary mirror is employed. In Johnson's first solution the center of the same mirror was used, but he quickly saw that the same rays would then pass the diagonal mirror twice, thus largely annulling the reduction in diffraction due to the reduced size of the diagonal mirror. He by-passed the diagonal by using an off-axis ellipsoidal mirror—that is, the side of a larger ellipsoidal—the remaining part being left nonfunctional

"This telescope," he wrote when he first proposed it in this department in July, 1944, "should approach the performance of a refractor more closely than any other type of reflector." Now that the first Johnsonian telescope has been built, he is able to write, "I have been using my new 10-inch modified Gregorian since last November, and am very pleased with its performance. I have had excellent views of Saturn and have seen nine belts on Jupiter.

"This telescope was designed primarily for planetary observing and has an equivalent focal length of 15 feet. The square skeleton tube is mainly of aluminum and the rest of the telescope is steel. For photographic use, a 40-pound war-surplus K-19 aerial camera with 13½-inch focal length, f3.5 Eastman anastigmat lens, is attached to the same mounting. The camera is not an integral part of the telescope When attached it shifts the tube's center of gravity toward the eyepiece, making it easier to reach.

"For a finder, a three-inch f5 war-surplus objective is mounted in the corner of the tube A war-surplus flat leads the light from this to a second flat, which may be slid into position in front of the eyepiece during use of the finder.

"The telescope pier is in the center of a 12-foot-square observing floor. An aluminum-covered housing protects the instrument when it is not in use.

"This type of telescope has a number of advantages. The secondary of the conventional 10-inch Cassegrainian or Gregorian telescope is usually about three inches in diameter, and the diagonal flat of a Newtonian about two inches. This large central obstruction causes extensive diffraction effects that impair definition. The modified Gregorian, however, has a central obstruction of less than ¾-inch diameter, reducing diffraction effects and improving definition. The loss of light due to the central obstruction is .5 per cent, compared with 5 or 10 per cent in the usual reflector. This gain, however, is approximately canceled by the loss in the third reflection. Hence the over-all transmission of light is about the same as in a conventional two-mirror telescope

"The long focal length is especially good for planetary observing, as it makes possible high powers with medium focal-length eyepieces. The slender cone of light favors the eyepiece but may increase the conspicuousness of 'ghosts' in some Ramsden and Kellner eyepieces, so I use mostly orthoscopic eyepieces and a Hastings triplet. With these I get magnifications of 180, 250 and 300 diameters and, with a Kellner eyepiece, occasionally up to 490—but at the Newtonian focus, as low as 38 diameters with two-degree field: nearly a richest-field telescope. A stop may be placed at or very near the primary focus to reduce stray light entering the eyepiece.

"The telescope may be arranged to use the Newtonian focus without disturbing the Gregorian flat in any way. The Newtonian eyepiece is so close to the Gregorian eyepiece that the same slow-motion controls may be used at either position.

"A conventional Cassegrainian or Gregorian must have a high pier, to permit comfortable access to the eyepiece at the lower end of the tube. Such an arrangement puts the Newtonian eyepiece high up where it is difficult to reach. A

modified Gregorian can use a lower pier, thus making both eyepieces more accessible. With my telescope I can observe any part of the sky without climbing more than 18 inches off the observing floor, and if I had built it with a rotating tube I would never have to climb at all. The lower pier also makes possible a smaller shelter or dome.

"Each mirror, primary and secondary, may be tested by itself. For the test there is no need for a large flat, and no possibility that errors in one mirror will mask those in another.

"The paraboloidal primary may be tested by the usual methods, but must be very accurate, as any errors in it will be magnified by the ellipsoid. It may be given a greater focal length than is possible with conventional Cassegrainians or Gregorians, making its testing and figuring easier, and also making it more suitable for use at the Newtonian focus. Paraboloids of medium focal length are easier to make than those of short focal length, and ellipsoids with small amplifying ratio are easier to make and test than those of higher amplifying ratio. It follows that modified Gregorians, with primary mirrors of f6 to f8 and secondaries of amplifying ratios from two to three, are much easier to make than conventional compound types, with primaries of f3 to f5 and ellipsoids of focal ratios from three to five."

These are the advantages of the Johnsonian.

THE six-inch ellipsoidal secondary proved to be much easier to make than the 10-inch paraboloid. It was to have a radius of curvature of 10.8 inches, or a speed of f 9, and almost half an inch of glass had to be removed from the center. This was done by hand tools—glass caster cups of 2⅜-inch, three-inch and four-inch diameter, used in that sequence. Grinding was concentrated in the center until a hollow of about the right curvature developed, and then the strokes were lengthened until this hollow spread to the edge of the disk. With No. 80 Carbo 22½ hours were required, and five caster cups were worn out.

"When the fine grinding was finished the mirror was given an hour's polishing and tested at the center of curvature. It was found to be a sphere. With the pinhole moved to the F_1 position and the knife-edge to the F_2 position, the apparent figure resembled that of an oblate spheroid tested at the center of curvature. The difference in knife-edge settings from center to edge was about three inches.

"Rough figuring was done with emery, alternated with short spells of polishing to permit testing. When figuring a semi-polished surface with emery it is easy to tell whether the tool is grinding in the right place, as the mirror loses its polish soonest in the zone where the grinding is greatest. It was necessary to return to emery six times before the surface was close enough to the desired ellipsoid to permit figuring by polishing. Most of the rough figuring was done with a three-inch tool.

"Ceria was used for most of the polishing, but it was found that the mirror was being scratched, so the job was finished with rouge. A soft, 2½-inch lap was found best for polishing so radical a departure from a sphere.

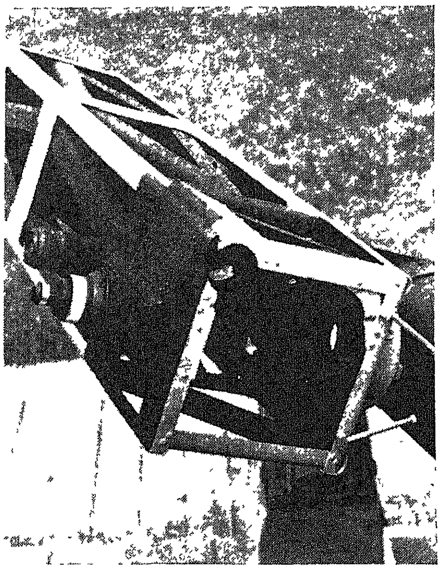
"In testing the ellipsoid the pinhole was placed at F_1 and the knife-edge at F_2. The desired ellipsoid darkens uniformly and appears flat, no zonal measurements being necessary. The pinhole was in the end of a ½-inch-diameter cylinder and was illuminated by a flashlight bulb, with a piece of ground glass between bulb and pinhole. Pinholes were made in heavy foil and were easily interchangeable.

"This test setup had two drawbacks. First, the mirror wasn't evenly illuminated by the pinhole, making it difficult to distinguish the shadows near the edge of the mirror. Also, convection currents that rose from the lamp housing after it had been in use for a few minutes made short periods advisable in testing. Nevertheless, the ellipsoid was figured with this setup. These drawbacks could be overcome by using the method described in *Amateur Telescope Making*, page 369: a drop of mercury on the end of a stick.

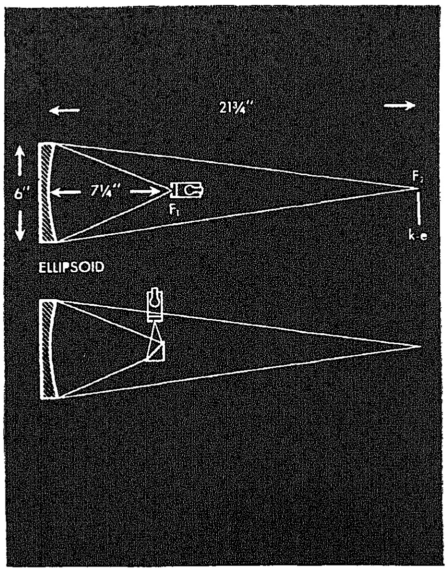
"As a further test a .165-inch eyepiece was placed at F_2 to examine the image. A number of pinholes were made in aluminum foil, and the smallest was selected. This was then partly closed by pushing the ragged edges back into the hole, leaving a very irregularly shaped hole with a length of .0015 inch. Details in the jagged edges of the hole, with dimensions of less than .0001 inch, could easily be seen. The theoretical resolving power of a 10-inch telescope is .45 second, which would be .00013 inch at the primary focus. Thus the ellipsoid takes full advantage of the resolving power of the primary. Any stretching or movement of the detail as the eyepiece is moved into or out of focus may indicate astigmatism. If the direction of such movement does not rotate with the mirror, the astigmatism is in the testing apparatus.

"In making any of these tests of the ellipsoid the apparatus had to be positioned very accurately. Luckily, the mirror was so close to F_2 that it could be moved with one hand while looking through the eyepiece. Coma becomes rather evident with any slight misalignment of the apparatus.

"The same apparatus was rearranged, as shown in the drawing on page 62, to test the small prism that was to be used,



Finder, objective, curved spider



Testing the ellipsoid and prism

with its hypotenuse face toward the reflected cone of rays, as a diagonal. The image was examined with the eyepiece. The prism was arranged so that almost the entire ellipsoid was illuminated. The prism-face dimensions needed were 7/16 by ¾ inch. The components were arranged almost as they are in the completed telescope, yet the sensitivity to error was much greater in the test, because the entire aperture instead of only an off-axis portion of the ellipsoid is used, and thus the light leaves the mirror in an $f4$ instead of an $f18$ cone Nearly the entire surface of the prism is used to form the image of a single point, while in the telescope only a 1/12-inch-diameter area is used to form the same image. The high-power (.165-inch) eyepiece used in the test would give much too high a magnification on the telescope—1,070 diameters.

"The tiny diagonal reflects the light to a two-inch portion of the six-inch ellipsoid. Actually, the flat was placed half an inch beyond the focus of the primary, since at the focus any dust on its surface would be sharply in focus at the eyepiece. Also, if the flat is placed inside the primary focus the ellipsoid may be so proportioned as to bring the eyepiece closer to the tube. (If it is desired to make photographs at the prime focus, the flat may be placed far enough outside the focus so that the film holder can be attached at the proper position without disturbing it. But with the flat outside the focus collimation would be more complicated.)

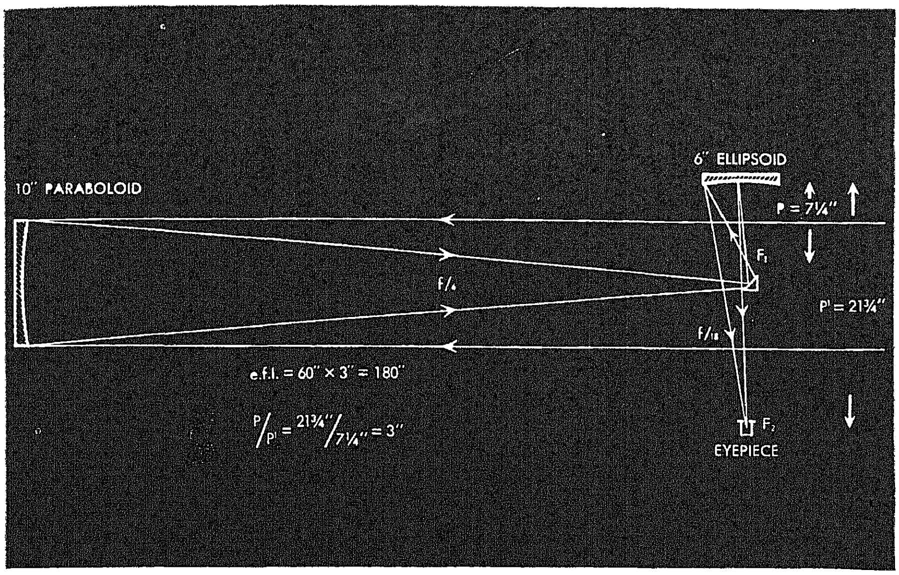
"As in any compound telescope, the optics must be held in rigid alignment and must be easily adjustable. For collimation, crosslines were scratched on the cell of the ellipsoid with their intersection over the center of the mirror. A tube 1¼ inch in diameter, with cross-hairs in one end and a peephole in the other, was placed in the eyepiece tube. The eyepiece mount was tilted until the cross-hairs, made of thread, were lined up with the cross-scratches on the cell of the ellipsoid. This tube was then removed from the eyepiece tube and a ring with cross-hairs placed over the end of the eyepiece tube.

"A frame with cross-hairs was then clamped to the diagonal mount in such a way that the cross-hairs could be adjusted until they were exactly at the primary focus. This frame was adjusted until its cross-hairs were in line with the cross-scratches on the ellipsoid cell and the cross-hairs at the end of the eyepiece tube. The cross-hairs were also adjusted until they were ½ inch from the center of the diagonal.

"The eyepiece mount was then focused until the distance between the two sets of threads was 14½ inches, which was the distance between F_1 and F_2 as determined when testing the ellipsoid. The ellipsoid was then adjusted, longitudinally and by tilting, until the thrice-magnified image of the first set of cross-hairs was coincident with the cross-hairs at the end of the eyepiece tube.

"To determine whether the image and the second set of cross-hairs were in the same plane, they were tested for parallax by watching them while moving the head from side to side. If there is no apparent movement of the image with respect to the second set of cross-threads, they are in the same plane. If the image moves in the same direction as the eye, it is farther from the eye, and the ellipsoid must be moved closer to the primary focus. If the cross-hairs move in the same direction as the eye relative to the image, the image is between them and the eye, and the ellipsoid must be moved away from the primary focus. The distance the mirror must be moved is one third the distance between the second set of cross-hairs and the image of the first set, so the test is very sensitive.

"With the ellipsoid properly adjusted, the diagonal could be adjusted. It was



Working principle of the Johnsonian telescope

moved longitudinally and tilted until the reflection of the lower end of the telescope tube was properly centered when looking into the eyepiece tube.

"The 10-inch paraboloid was then attached to the tube and squared approximately. The ring with cross-hairs was removed from the eyepiece tube and an eyepiece inserted. The paraboloid was moved longitudinally until the primary focus was coincident with the cross-hairs. This may be done with great accuracy by focusing the telescope on a distant object and then moving the paraboloid until the cross-hairs and the image of the distant object are in the same plane. This was tested by the parallax method, just as when adjusting the ellipsoid, except that now an eyepiece was used. If the object image appears to be beyond the cross-hair image, the mirror is too far down the tube and must be moved up.

"The mirror was first adjusted on a house two miles distant, but when turned on a house four miles distant was found to require readjustment, so the final adjustment was made on the moon.

"The paraboloid was then accurately squared on, making use of a dot of paint in its exact center. The position of the image plane was again checked. The cross-hairs were removed from the diagonal mount, as the telescope was now in collimation and ready for use.

"The parallax method of adjusting the mirror was found to be so sensitive that the focal plane of the primary could actually be located precisely between the two crossing threads, which moved in opposite directions when the observer moved his head.

"A Newtonian of the conventional $f8$ ratio can be made more suitable for planetary observation by converting it to an $f16$ or $f18$ modified Gregorian. To convert a 10-inch telescope from $f8$ to $f18$ or longer, the ellipsoid would be made, for example, from a 4½-inch Pyrex disk. The radius of curvature would be 8¾ inches, sagitta ¼ inch, p would be six inches and p' 13½ inches. To get a field one inch in diameter at the eyepiece a .56-inch flat would be needed. If the Newtonian does not have a first-class paraboloid, however, it would be a waste of time to convert it.

"The modified Gregorian has a doubly inverted field. North is at the top and west at the left, just as on a map.

"The following formulas may be used for determining the mirror proportions when the small flat is inside of the prime focus. The formulas are not all exact, since some approximations were made in their derivation, but they are close enough for use.

"Diameter of field at secondary focus$=I$

"Diameter of field at prime focus$=i=I/A$

"Amplification factor, ellipsoid$=A=p'/p$

"Mirror diameter$=M$

"Focal length of primary$=F$

"Equivalent focal length$=AF$

"Distance, primary focus to flat$=b$

"Width of flat$=E=[Mb+i(M-b)]/F$

"Diameter of off-axis portion of ellipsoid used$=D=[MP+i(F+p)]/F$

"Diameter of cone between off-axis part of ellipsoid and eyepiece at point where it crosses optical axis$=C=[(p'-p-b)\ (D-I)/p']+I$

"If the small diagonal were outside of the prime focus, $+\ b$ would be used in the formula for C, all other formulas remaining the same.

"Distance from center of ellipsoid to edge of off-axis area of ellipsoid$=d=pp'[(C+E)/2\ (p+b)\ (p'-p)]-D/2$

"Minimum radius of blank needed to make ellipsoid$=r=D+d$

"Radius of curvature of ellipsoid$=R=2p'p/(p'+p)$

"Remaining to be completed are the driving clock, right ascension circle, eyepiece and flat for the Newtonian focus."

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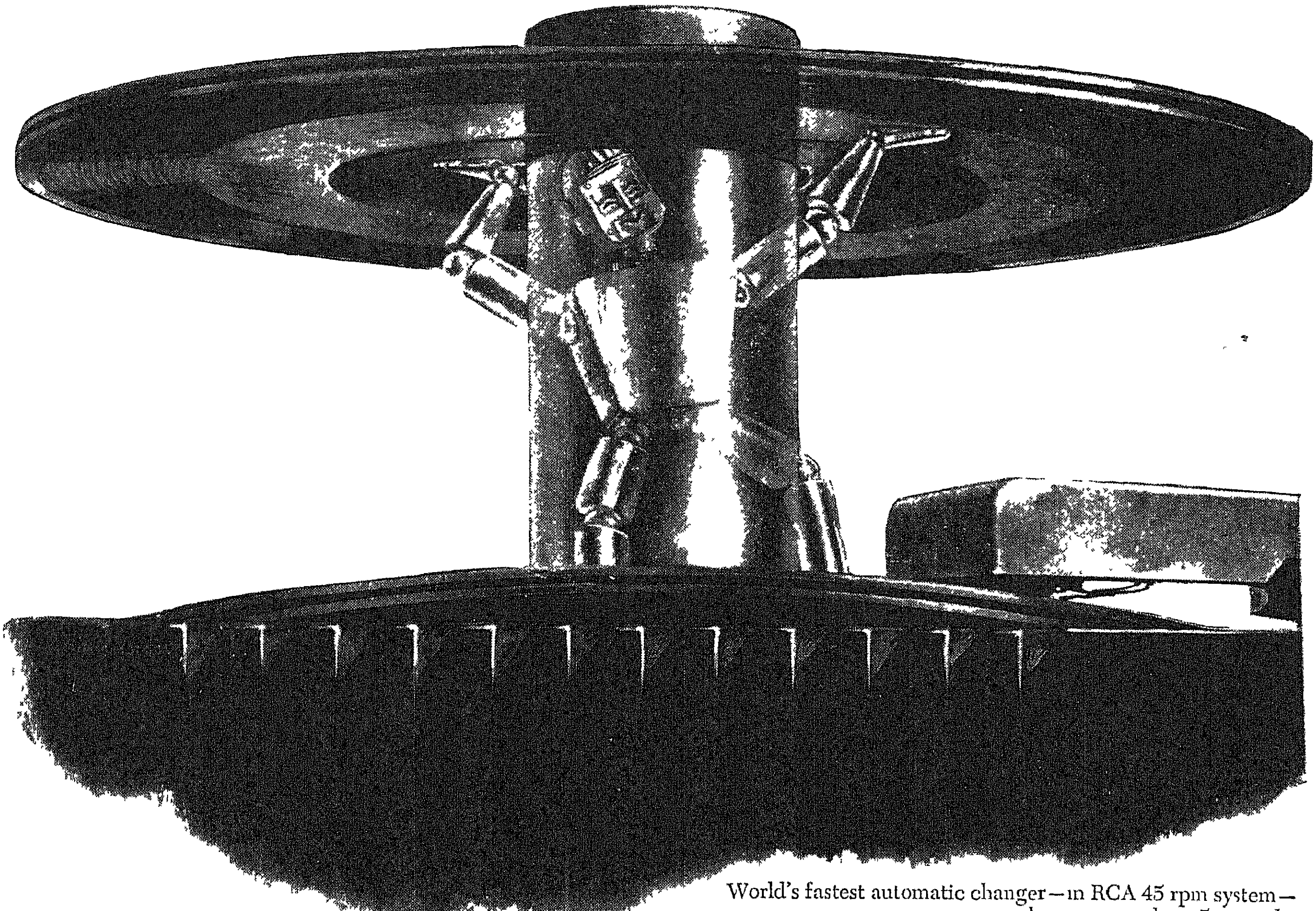

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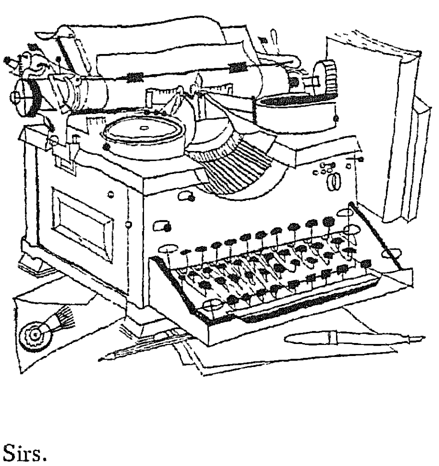

LETTERS

Sirs.

The tendency of the pendulum of opinion to overswing is quite as noticeable in the scientific world as elsewhere. Only a few years ago D. M Barringer and his associates were waging an uphill but eventually successful campaign in the pages of the *Scientific American* to prove that *one* terrestrial meteorite crater (and that the most obvious one) actually had its origin in meteoritic impact. In the July issue of the same magazine Ralph B. Baldwin takes the position that *all* of the millions of craters on the moon are meteorite craters. Furthermore, Baldwin's extravagant views have been sanctioned in the first published review of his recent book, *The Face of the Moon* (see Fred L. Whipple, *Sky and Telescope*, August, 1949, pp 258-59).

The satisfaction felt by meteoriticists that scientists of the caliber of Baldwin and Whipple are now actively engaged in the development of meteoritics, a field too long ignored by the geologist and the astronomer, must be tempered by concern that hasty acceptance of such extreme views as Baldwin's react to discredit the new science. This letter has its origin in such concern. Its purpose is to raise a number of objections which either render most improbable Baldwin's thesis that all lunar craters are of impact (*i e., extrinsic*) origin; or which bring out certain redundancies or inadequacies in the evidence Baldwin has presented in support of his views; or which make clear that in his precipitate abandonment of all *intrinsic* theories of lunar crater formation, he has entirely escaped coming to grips with the most modern and, in the writer's opinion, the best-founded explanation of the craters on the moon, exclusive of the so-called ray craters.

Summarized briefly, these objections are as follows: 1) It is extremely unlikely that the observed distribution of craters on the moon arose by chance, as would necessarily be the case if these craters had been produced by a random fall of meteorites on the lunar surface. 2) Contrary to Baldwin's conclusion that only meteoritic impact explosions could produce on the moon craters with the characteristics observed in the lunar craters, the most recent intrinsic theory of the origin of these craters not only provides craters which conform quite as well as explosion craters to the various empirical relations discovered by the study of individual lunar craters, but also actually predicts such general lunar features as the polygonal rather than circular shape of most of the large craters. 3) Baldwin, by adopting C C Wylie's estimates of the mass of the meteorite which created the great crater at Canyon Diablo, Ariz., is enabled to ascribe even the largest of the lunar craters to the impact of meteorites of amazingly small size. Actually the estimates of Wylie have been shown to be quite unrealistic Hence the impact explosions of such cosmic pebbles as Baldwin describes are not competent to produce the huge craters credited to them. 4) Baldwin cites the relationship between crater-diameter and rim-height as evidence for the explosive origin of the lunar craters in addition to evidence afforded by the diameter-depth relation. However, the relation between diameter and rim-height is a simple consequence of the diameter-depth relation in view of Schröter's Law and the proportionality between rim-width and crater-diameter.

Only the first two of the above objections can be developed in any detail in this letter Objection No. 1 is based on the fact that were the lunar craters, as Baldwin supposes, the result of meteorite impacts on the face of the moon, the centers of these craters would constitute a set of points distributed at random over the lunar surface. It is evident that falling meteorites would strike at random on the surface of such celestial bodies as the earth and the moon. However, in the case of the moon, the distribution of crater-centers is not at all random. This follows not from the easily perceived nonuniformity of the distribution in question, as some writers have supposed, but from discrepancies existing between the observed distribution of the lunar craters and the distribution predicted by the theory of probability.

In 1940 William Scott, one of the writer's students at Ohio State University, applied the probability theory outlined above to a group of 3,112 typical lunar craters, comprising all craters for which satisfactory position data are given in M. A. Blagg's compendious work, *Lunar Formations* The results obtained by Scott show that it is extremely unlikely that the observed distribution of the more than 3,000 lunar craters considered is the result of chance. On the other hand, the distribution of a special class of lunar craters, the so-called ray craters, conforms rather closely to the theoretical random distribution for this class.

We preface our development of objection No 2 by recalling several facts once familiar to all selenographers, but apparently lost sight of by many in modern times. It has long been known that most of the large craters on the moon have a *polygonal* rather than a circular form, where several neighboring craters exhibit *hexagonal* form, it is evident that at the time of origin of these craters, several regularly spaced centers of lateral pressure were in action simultaneously in the outer shell of the moon. Such a dynamical situation is quite inexplicable under Baldwin's meteoritic hypothesis, but is a necessary consequence of a new convection-current theory of the lunar craters.

The French astronomer P. Puiseux, from his exhaustive study of polygonal forms on the moon, was led to the discovery of a rhomboidal network of dikes and rills on the lunar surface, the lines of this network often almost coinciding with one or more of the edges of craters or ring plains of hexagonal shape. Occasionally he found a hexagonal crater which exactly filled out a mesh of his rill system. From a careful examination of the interrelations between the rill net and the craters, Puiseux came to the conclusion that the net constituted a primary, and the hexagonal craters a second-

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ary, feature of the lunar surface The meteoritic impact theory of Baldwin gives an explanation of neither the primary nor the secondary selenographic features discovered by Puiseux. However, the convection-current theory of the lunar craters recently developed by the distinguished astrophysicist J. Wasiutyński actually predicts the formation on the lunar surface of both Puiseux's network and the lunar craters.

Basic to the new theory is the work of H. Bénard and Lord Rayleigh on convection currents in gravitationally unstable layers of fluid heated on the under side. Wasiutyński applied the convection-current theory to a stratum of liquid basalt below the outermost shell of the moon. This explains first the formation of the "seas" or maria (large exposures of basaltic rock more or less completely cleared of light overlying granitic material by convection currents), second the development of the rill systems of Puiseux and third the formation of closed mountain chains and craters conforming to the Puiseux net.

Not to be outdone by proponents of the volcanic and meteoritic theories who point with conviction to terrestrial examples of craters originating by the favored process, Wasiutyński has set forth in most convincing detail the close analogy between certain terrestrial features—the stone and fissure polygons of the subpolar regions—and the lunar craters. The striking success of the convection-current theory in simply explaining the remarkable fields of roughly hexagonal stone and fissure polygons on the island of Spitzbergen, for which dozens of involved explanations have been offered in the last half-century, cannot fail to impress the reader. Wasiutyński even seeks to explain the lunar ray craters solely on the basis of convection currents, but here, in the writer's opinion, too much is at last expected of the convection theory. On the one hand, this theory would not predict a random distribution of the ray craters on the moon; and, on the other, Wasiutyński's explanation of how ray systems can develop on the maria is in contradiction to his earlier explanation of why rills on the maria, where there was no granite at the top, were almost completely obliterated by the inflow of liquid basic magma from the basalt layer. The discrepancies just alluded to and the highly significant fact that the great majority of the ray craters are situated on the maria (*i e.*, on those undisturbed areas of the moon continuously exposed for the longest time to meteoritic impact) give support to the writer's belief that the lunar ray craters are meteorite craters.

LINCOLN LAPAZ

Director, Institute of Meteoritics
The University of New Mexico
Albuquerque, N. M.

50 AND 100 YEARS AGO

OCTOBER 1899. "With the death of Bunsen there has passed away the last of those great German chemists of the middle of the present century, chemists who bore the greatest part of the work of laying the foundation of the present science, and through whose efforts their fatherland has taken the first place in chemistry among the nations of the earth. The century began with Wöhler and Liebig; in the next decade came first Bunsen and then Hofmann and Kolbe and Fresenius; perhaps to these we should add Kekulé, who followed ten years later. And now the last of these giants is gone. Liebig was the first to be taken. The last ten years have seen the death of Hofmann, Kekulé, Fresenius, and now, at the close of the century, only a few months before the hundredth anniversary of Wohler's birth, Bunsen is dead."

"Through the enterprise of the New York *Herald*, the public has been made acquainted in a very practical way with the great advantages which result from the use of what is now popularly known as the 'Marconi system of wireless telegraphy.' The world-wide interest which is being taken in the present international yacht races renders the instant transmission of the progress of the race a matter of actual importance, and the saving of a few hours time, which is rendered possible by wireless telegraphy, led to the bringing of Mr. Marconi to this country in order that he might report the races from a steamer which accompanies the yachts over the course. From the steamer the messages were sent to New York, where they were distributed throughout the world."

"In a general way the battery of an automobile may be compared with the horse. Both may be overworked with disastrous results. Both are better off when not subjected to sudden starts, and both will last longer if not constantly pushed to the utmost capacity. Both renew their strength and usefulness after a reasonable rest; and last, but not least, both require when ill the care of an expert—the horse the veterinary surgeon, and the battery the skilled electrician."

"For the protection of the public, we wish to enter an earnest protest against the commercial exploitation of comparatively untried inventions of which so much is going on in various parts of the country. The most flagrant examples of this sort of thing are to be found in the starting of companies and the selling of stock for the promotion of liquid air schemes. We do not say that any of these are deliberate attempts to obtain money falsely, but we do say that the nature of the liquid air apparatus, whether it be in the form of motor, refrigerator, explosive or what not, the absence of any demonstrated facts to establish its value, render it our duty to warn the readers of the *Scientific American* against investing their money in enterprises which exist only in the imagination of their promoters."

"The Holland submarine torpedo boat made another excellent run on October 6, in little Peconic Bay. A German naval constructor who is visiting the United States was on board the submarine boat. He was favorably impressed with the mechanism of the vessel and was pleased with her performance. He was of the opinion that in the hands of competent men the boat would prove a formidable weapon."

"One great reason for the popularity of the automobile is that it can be more readily managed by women than horse-drawn vehicles. Many women object to driving horses on account of their liability to shy or bolt. The automobile offers remarkable advantages in their respect, but no lady should try running an automobile until she thoroughly understands the mechanism."

OCTOBER 1849. "The subject of a Railroad to the Pacific is now engaging much of the public attention. That a railroad from the United States to the future states of the Pacific, will have to be built at no distant day, no one doubts, but the way to do this, and the most proper routes to be adopted, are subjects which will require no small amount of reflection. We take no part in the discussion of this or that scheme to build an Atlantic-Pacific Railroad. We believe that the times are not yet ripe for its construction."

"The *Cleveland Plain Dealer*, of Oct. 5, has a letter announcing the arrival of Sir John Richardson, from the fruitless search after the lost Polar expedition of Sir John Franklin, of whose dreadful fate among the ices of the Arctic Ocean, there is left little or no room to doubt. Sir John Richardson having failed to find even the remotest clue to the Franklin Expedition is now on his way back to England. He speaks confidently of the existence of a northern passage, practicability, he says, is another question, the summers being only from 38 to 60 days long."

"A system of meteorological observations will soon be commenced under the supervision of Prof. Henry, of the Smithsonian Institute, who was here a few weeks ago about the instruments."

"Oregon is the greatest lumber country in the world. Around one mill, within a circle of three miles, stands timber enough to last a hundred years, the mill all the time cutting 6,000 feet a day."

"The *London Medical Gazette* states that a most important discovery has just been made known by certain Doctors Snow, Budd and Brittan, and other celebrated physicians, respecting the cholera. They have prepared a very long report, which will soon be published, in which they show that the cause of malignant cholera is 'a living organism of distinct species.' Dr. Budd procured water from different parts of London, and detected organisms in great numbers in every specimen of drinking water. He states, in a long letter to the *London Times*, that this organism is of the fungus tribe, and is taken, by the act of swallowing, into the intestinal canal, and there becomes 'infinitely multiplied by the self-propagation which is characteristic of living beings.' The pressure and propagation of these organisms, and the action they exert, are the cause of the peculiar flux which is characteristic of malignant cholera. These organisms are disseminated in the air, in the shape of impalpable particles, in contact with articles of food, and principally in the drinking water of infected places. The evidence on which these conclusions are founded, has been placed in the hands of the President of the College of Physicians."

"Mr. E. Brown, of Preston, Eng., has discovered a mode of reducing hydrogen gas to a liquid. A paper on the subject is soon to be presented to the Royal Society."

He finds trouble by ear

As this cableman runs his pickup coil along the cable, his ear tells him when he has hit the *exact spot* where unseen trouble is interfering with somebody's telephone service.

Trouble develops when water enters a cable sheath cracked perhaps by a bullet or a flying stone. With insulation damaged, currents stray from one wire to another or to the sheath. At the telephone office, electrical tests on the faulty wires tell a repairman approximately where to look for the damage.

A special "tracer" current, sent over the faulty wires, generates a magnetic field. Held against the sheath, an exploring coil picks up the distinctive tracer signal and sends it through an amplifier on the man's belt to headphones. A change in signal strength along the cable tells the exact location of the "fault."

Compact, light, simple to use, this test set makes it easier for repairmen to keep your line in order. It is another example of how Bell Laboratories research helps make Bell Telephone service the most dependable in the world.

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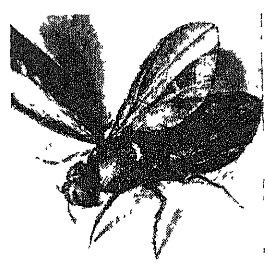


THE COVER

This month's cover painting is a greatly enlarged portrait of *Drosophila melanogaster*, the fruit fly, whose heredity has been more intensively studied than that of any other organism. The object projecting into the picture from the upper left is a needle with which the fly is manipulated under a low-power microscope. Because of the ease and rapidity with which it can be bred in the laboratory, *Drosophila* has been a favorite with geneticists since the pioneer work of Thomas Hunt Morgan. The University of California's Richard B. Goldschmidt and others have found that a great many variant forms of *Drosophila* can be produced by applying to the young pupa different types of sublethal shock such as radiation, extreme temperatures or treatment with certain chemicals (*see page 46*).

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
11-15	William Auerbach-Levy
16	Eric Mose
19	R. W. St. Clair
20-21	U. S. Atomic Energy Commission
22-23	A. Brotman
24	Eric Ashby
30	National Tuberculosis Association
32-33	Rockefeller Institute for Medical Research
34	Irving Geis
35	Radio Corporation of America (*top*); Hubert Bloch, Rockefeller Institute for Medical Research
37	Hubert Bloch
38	Gardner Middlebrook, Rockefeller Institute for Medical Research
40	Vernon Knight, Cornell University Medical College
41	Irving Geis
43-45	Eric Mose
47-49	Ramon Gordon
51-54	David Stone Martin
56	*The Story of Maps*, by Lloyd A. Brown; Little, Brown and Company
60-62	A. Brotman

What GENERAL ELECTRIC People Are Saying

H. C. POLLOCK

Research Laboratory

ATOM SMASHERS: The electrical constitution of matter has become understood only since the turn of the century. The fact that the principal constituent of matter, the atom, is made up of a central positive core, the nucleus, which is surrounded by negatively charged electrons became accepted after 1911 from the work of Rutherford. Since that time the most important details of atomic structure have been fairly well worked out. During recent years the physicist has shifted his attention to the nucleus, the center of the atom. What keeps the protons and neutrons together despite the enormous repulsive forces between the protons? To answer this and similar questions, it is very useful to have beams of very highly accelerated projectiles with which to bombard the nucleus, to study scattering, to cause disintegrations, and to produce new particles in the field of the nucleus. The projectile particles are electrons, protons, deuterons, and alpha particles. The effort to impart to these particles very high energies, corresponding to a drop through electric fields of millions of volts, has led to great engineering progress in the design of accelerating machines . . .

When the interest is in obtaining one-hundred-million-volt particles —and so on up—then it is necessary to use new principles . . . Machines are now being built in which the elementary particles can obtain energies corresponding to millions or even billions of volts without any such formidable potentials being present in the machine. Such machines are the cyclotron, the betatron, the synchrotron, the synchrocyclotron, and the linear accelerator . . .

Perhaps the most exciting discovery in recent months with the large accelerators . . . is that they can knock out of the nucleus particles named mesons, hitherto found only in cosmic radiation. The whole of our knowledge, or rather ignorance, of mesons and their properties is in a very rapid state of flux. Apparently there are several kinds of mesons and they may be charged positively, negatively, or perhaps not at all. There are heavy mesons . . . and there are light mesons . . . With the very high-energy accelerators one can knock the heavy mesons out of all kinds of nuclei. The heavy negative mesons are very apt then to cause further nuclear disintegrations . . . The heavy positive mesons tend to decay into light mesons. The light mesons again decay quickly, emitting an electron . . .

It is only natural to look beyond the present huge machines and to extend their principles to the limit. In England a proton accelerator for 1.3 billion electron-volts is well along toward completion. At Brookhaven a 3 billion electron-volt machine has been started. And in California at Berkeley there will be a 6 billion electron-volt machine. The completion of these machines in the next five to ten years may lead to even more dramatic discoveries about the nucleus or the nuclear particles.

University of Virginia,
April 25, 1949

★

MATTHEW LUCKIESH
A. H. TAYLOR
THOMAS KNOWLES

Lamp Research Laboratory

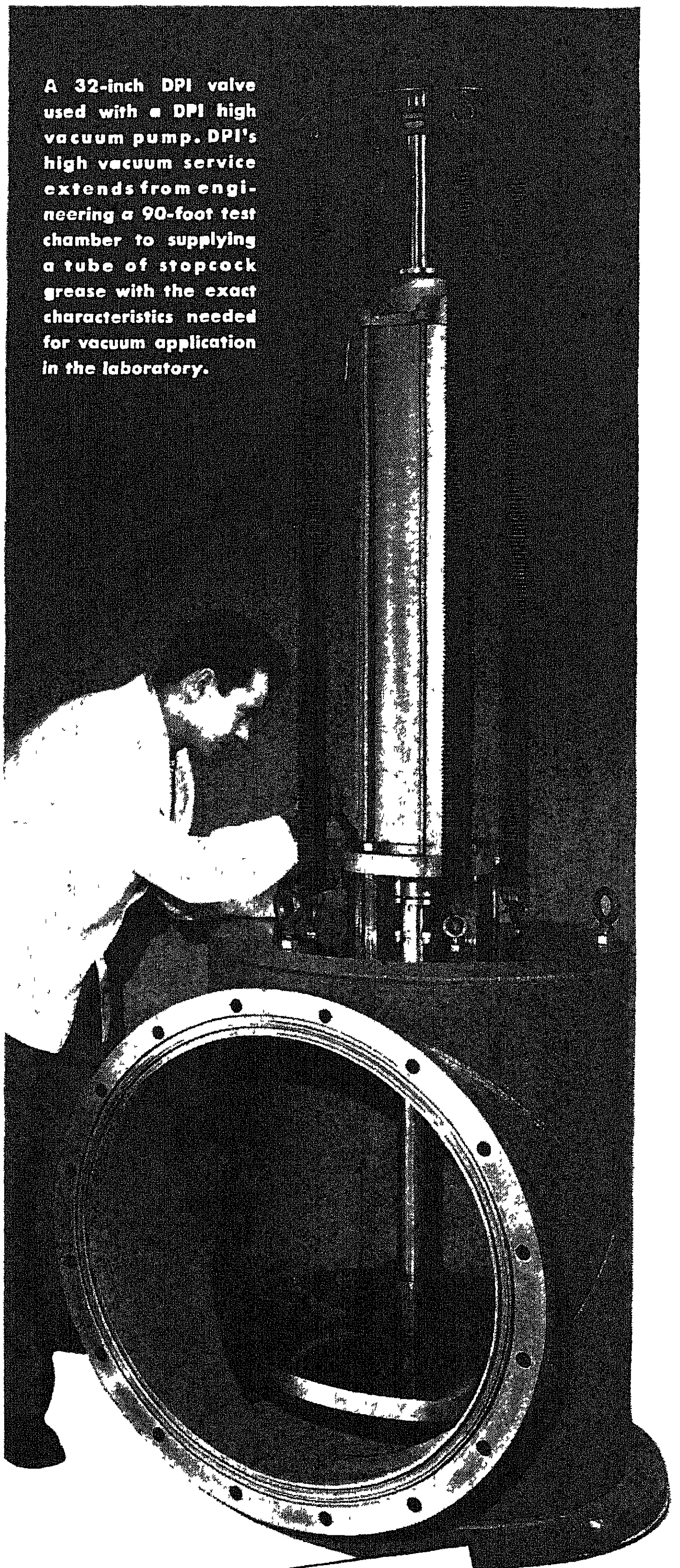
AIR DISINFECTION: The oldest and commonest method of reducing the bacterial content of air in occupied rooms is by ventilation, which replaces contaminated room air by filtered or outdoor air. While this might reasonably be expected to reduce the concentration of airborne organisms by dilution, Yaglou and Wilson found that a high-velocity air stream which stirred up the floor dust actually increased the bacterial content of the air with increasing numbers of air changes per hour. Furthermore, there is a practical limit to the frequency of air changes because of the creation of drafts which add to the discomfort of the room occupants. In the cooler climates, the economic aspect of increased air changes cannot be ignored.

Another method of air disinfection is the use of aerosols which are added to the room air by suitable vaporizing apparatus.

The third method, which is the principal subject of . . . our researches for many years, is the use of short-wave ultraviolet energy radiated by so-called germicidal lamps. These lamps are very efficient sources of $\lambda 2537$ energy, which is in the spectral region of maximum germicidal effectiveness. Since this ultraviolet energy can produce conjunctivitis and erythema if the eyes and skin are exposed to it for a sufficient period, special fixtures and installations have been developed for these lamps. The fixtures, employing reflectors of suitable material, are usually mounted on the walls to project the germicidal energy across the room above eye-level. Most oil paints reflect less than 10 per cent of this energy, hence relatively little is reflected by ceiling and walls into the lower occupied part of the room. It has been found that this method is safe and effective . . .

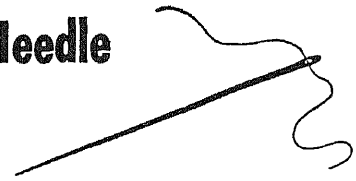
A single 30-watt germicidal lamp in a suitable fixture consumes approximately 40 watts in lamp and auxiliary. Extensive data indicate that, for occupied rooms, one of these units is sufficient for a floor area of approximately 200 to 300 square feet if properly designed and installed. The cost of operating such a fixture eight hours daily, including lamp renewal and reasonable amortization of the original cost, is of the order of one dollar a month at the present time.

General Electric Review,
August, 1949



A 32-inch DPI valve used with a DPI high vacuum pump. DPI's high vacuum service extends from engineering a 90-foot test chamber to supplying a tube of stopcock grease with the exact characteristics needed for vacuum application in the laboratory.

16 Trillion Abreast Could March Through the Eye of a Needle



SURE, BUT MOLECULES IN HIGH VACUUM DON'T MARCH ABREAST—THEY JUST WANDER

A HIGH VACUUM diffusion pump doesn't suck. It's just a scheme that makes it easier for molecules to wander out of a system than to wander in. Since they get out only by random wandering, valves for some high vacuum jobs get to be as big as the 32-incher on the left in order not to hinder the drift of the molecules.

Wonderful things can come true once enough molecules have drifted out.

With few air molecules to bump into, other molecules can be shot quickly and cheaply onto a piece of plastic to make a beautiful belt buckle or onto a piece of glass to make a sharp-cutting optical interference filter.

A synchro-cyclotron can whirl protons around a quarter-million times in a few thousandths of a second to give physicists new information about mesons.

Plasticizers that don't evaporate out of the plastics they're put into are themselves prepared by flash distillation at high temperatures from crude mixtures.

Metals get rid of tenacious gases that degrade their mechanical and electrical properties. Other metals that were laboratory curiosities become engineering materials because they can be kept out of chemical combination at a critical stage of refining.

Your high vacuum problem may be quite different. Why not find out what DPI experience and equipment can do with it? Write

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SCIENTIFIC AMERICAN

Established 1845

CONTENTS FOR OCTOBER 1949 — VOLUME 181, NUMBER 4

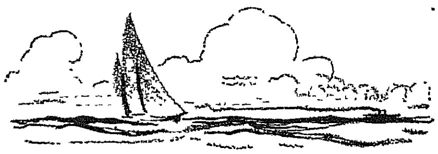
ARTICLES

DEPARTMENTS

In the days when cattlemen drove their stock across the unfenced prairie to the railhead, it was common practice among the least scrupulous to feed the cattle plenty of salt before they were offered for sale. When they were allowed to drink their fill, the gain in weight was the buyer's loss. Hence the term "watered stock" sensationalized in early days of corporation revelations and regulations.

Print from Bettman Archive

Are you selling "WATERED STOCK?"



WATER is just about our commonest material. In many places it is indispensable; in some places it is beautiful; but in others it contributes nothing but extra weight and the risk of depreciation. To send a six-ounce orange North from Florida freight must be paid on over five ounces of water which the North has in abundance — and then it must be eaten quickly before it rots.

BLOOD PLASMA

When World War II darkened the horizon Army doctors looked beyond the outright slaughter to the millions of wounded who might die in the field. Blood transfusion could save many but in a remote, devastated theater of war it was unthinkable — unless blood collected from a healthy population could be reduced, preserved, transported and reconstituted. To make this possible National Research Corporation took low temperature, high vacuum dehydration from the laboratory and developed it to the level of mass production.

PENICILLIN

Faced with an urgent wartime need for a universal antiseptic the English recalled the experience of Alexander Fleming with the blue-green mold, Penicillium Notatum. Under pressure the wonder antibiotic was accumulated — enough for a mouse, enough for a man, enough for twenty men — and then, grown by "kitchen culture" in millions of milk bottles, enough for an army. Again there was need for dehydration without heat damage and National Research's high vacuum process now installed in substantially all of the larger plants throughout the world, turned penicillin into powder at a rate to supply the world.

ORANGE JUICE

During the war we experimented with the dehydration of many common foods; meat, fish, vegetables, fruits, coffee. Of these orange juice was the most promising with a nationwide market ready and a world market waiting. We had produced citrus concentrate and powder on a pilot plant scale. Near the war's end we organized Vacuum Foods Corporation. For them we built and equipped a plant in Florida that now concentrates, for the national market, 75,000 gallons of juice a day.

This new industry, producing some 4½ million cans in the 1946–47 season is expected to reach an annual production rate of 200 million in 1949. Within five years it is predicted that one-fourth of all Florida's oranges will reach their market as concentrated juice. In this industry Vacuum Foods is the pioneer and leader.

COFFEE

The success story of orange juice will, we hope, be rewritten for coffee. For over a year we have been producing in small quantity a "crystalline coffee" — pure coffee essence, nothing more and *nothing less*. This small production is being market-tested through the local retail trade and a steadily increasing number of users have found out that coffee *can* be reduced to an instantly soluble concentrate, and still taste like good coffee.

WHAT NEXT

To anyone who is selling "watered stock," not with guile but from necessity, National Research can offer a new prospect — lower cost methods of producing dry materials with instantaneously soluble structure. To apply our proven techniques of high vacuum dehydration National Research Corporation stands ready with a carefully chosen, experienced staff, with the newest equipment and with an accumulated knowledge of large scale low temperature dehydration that cannot be equalled anywhere.

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SCIENTIFIC AMERICAN

OCTOBER 1949 VOL. 181, NO. 4

VISIT TO DUBLIN

In which a noted theoretical physicist calls upon the remarkable little group of eminent scientists at Ireland's exotic Institute for Advanced Studies

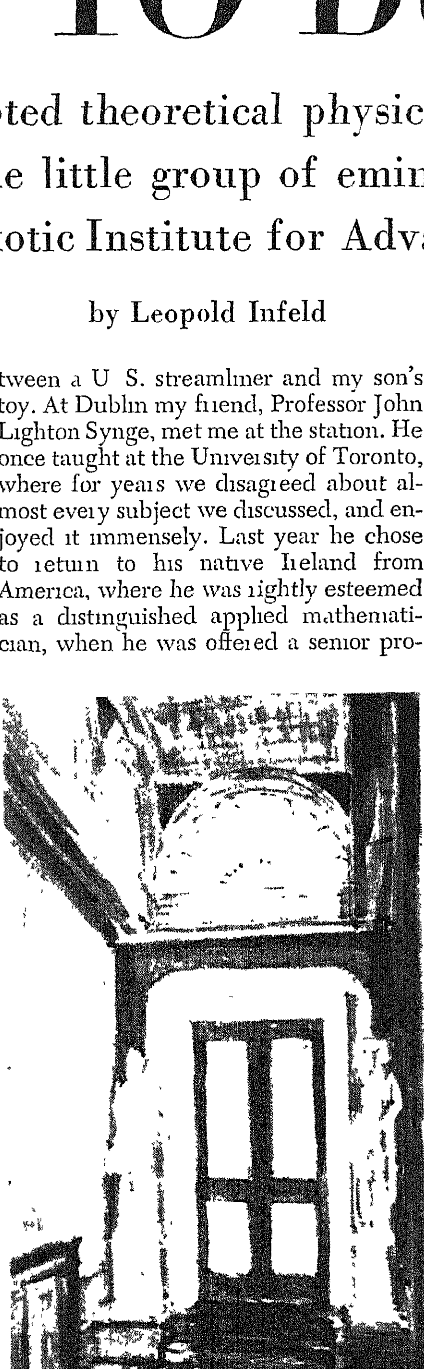
by Leopold Infeld

BY my watch, the plane landed at noon. A hostess with red hair and green eyes, in a shamrock-green uniform, announced in a sweet Irish brogue. "You are in Shannon, Ireland. It is now 4.55 p.m. local time. All passengers are requested to leave."

My first contact with Europe after 13 years looked good to me. The immigration officer at the airport asked why I had come to Ireland I told him I had been invited to lecture at Dublin's Institute for Advanced Studies. At once the officer became very friendly and began to talk about the Institute I was in a country where the title of Professor is a badge of honor, not of failure. Even the customs officers were helpful. I had been warned that they were terrors, that they minutely examine one piece of luggage after another, especially anxious to discover nylon stockings. I found them like all Irishmen· they love to philosophize and they are never in a hurry It is a country where leisure as well as scholarship is appreciated.

Outside the splendid Shannon airport a rickety, almost disintegrating bus was waiting. It had a conductor, driver and two passengers. They all fell into a long discussion for my benefit about the relative merits of the town's two hotels. Since they could not agree among themselves, I decided for the nearest. It had a wonderful garden and the air smelled of spring and flowers. (I wish someone would explain why the smell of the European air is so different from the American; I have never heard a hypothesis to account for this phenomenon of nature, but everyone who has visited both continents agrees that it is a fact.)

Next morning I was on my way to Dublin by a train that was a cross between a U S. streamliner and my son's toy. At Dublin my friend, Professor John Lighton Synge, met me at the station. He once taught at the University of Toronto, where for years we disagreed about almost every subject we discussed, and enjoyed it immensely. Last year he chose to return to his native Ireland from America, where he was rightly esteemed as a distinguished applied mathematician, when he was offered a senior professorship at the Institute for Advanced Studies



CLASSICAL ENTRANCE is inside the School of Cosmic Physics, housed in one of Institute's two buildings.

Dublin, upon which I was setting eyes for the first time, looked to me just as I had expected it to, only more so. I was starved for an old town, for aged scenery. I found Dublin enchanting. Its buildings are simple and austere, against this serious architectural background the Dubliners appear doubly gay and vivid. I experienced the long-missed pleasure of walking through streets charged with long and violent memories.

On opposite sides of Merrion Square stand the two buildings of the Institute, one the School of Theoretical Physics, the other the School of Cosmic Physics. Each School has three senior professors; those in the School of Theoretical Physics, in order of seniority, are: Erwin Schrodinger, Walter Heitler and Synge. The Institute, which draws students from all parts of the earth, has put the name of Ireland on the world map of scientific achievement. Yet its influence upon its own country, upon Irish intellectual life and universities, is small. In its cloistered isolation the Institute is a miniature of Ireland itself, whose problems and fights as a nation are not those of the rest of the world.

I was tense because of my approaching lecture. I had not often spoken to such a distinguished audience as I was about to face. The subject I had chosen was a highly specialized one· some recent work on the general theory of relativity which I had done with Albert Einstein. It dealt with a problem that we had first tackled 12 years ago but had been solved only in the last few months.

The problem has to do with the motions of double stars (*see page 42*).

PRINCIPAL OCCUPANTS of the Institute are shown in this group portrait. At the far right is author Infeld. At the far left is Walter Heitler, best known for his work in applying the quantum theory to chemistry. Second from the left is John Lighton Synge, a noted applied mathematician. Third is Erwin Schrödinger, originator

Imagine two stars of comparable mass moving around each other in space We have no direct, precise observations to guide us as to the relative motions in such a system, for in our own solar system the masses of the revolving planets are small compared with that of the sun. The motions of double stars have been worked out theoretically on the basis of classical Newtonian mechanics. But what is the answer of relativity theory, which describes the phenomena of gravitation better, more deeply and with greater logical simplicity than does classical theory? Paradoxically, the very fact that the general relativity theory is logically simpler makes the problem of deducing the laws of motion much more difficult in relativity theory than in Newtonian theory. The reason is that in relativity theory we assume much less than in classical mechanics, consequently we must deduce much more. It is this task of deducing laws of motion from the laws of the gravitational field that has proved to be difficult.

We believe, however, that we have now derived correctly the laws of motion of a double star, and that we know how the true motions differ from those predicted by the old Newtonian laws And we believe, too, that the laws cannot be refined much beyond the form in which we have deduced them.

It would be difficult to imagine any place in the world where a better audience for such a lecture could be found than at the Dublin Institute The often-heard saying that only 12 people understand relativity theory is utterly stupid. Every modern theoretical physicist understands it. But it is true that relativity theory is not today the center of interest among theoretical physicists; the focus of modern research is nuclear theory and quantum electrodynamics. Few physicists in recent years have done any creative work in relativity. But among those few are two of the three senior professors at Dublin—Schrödinger and Synge. These men are justly recognized as two of the best specialists in this field.

When I presented myself at the simple but dignified offices of the Institute on the morning of the lecture, I learned that Eamon de Valera had just telephoned that he intended to come to it. A few minutes before my lecture I met de Valera in Synge's office. His face looks even more ascetic than in his photographs, and the impression of strength through asceticism was heightened by a dark suit and tie (I was told that he always dresses in black.) In private conversation he speaks softly He did not appear at all out of place in the calm surroundings of the Institute, he could easily have been mistaken for one of the senior professors, except for the fact that he conducted himself in its halls with the subdued awe that most people reserve for church. Indeed, he is very proud of the Institute, it was his idea and his creation. Now that he is only the leader of the opposition in Ireland, the Institute remains, along with the independence of his country, as one of the few deeds of his life that the government cannot change.

We went together to the small lecture room, and I found with great pleasure that the room was crowded. (Like most lecturers, I do not much care whether the audience is small or large, as long as the lecture room is filled.) It was espe-

of wave mechanics and author of the famous book *What Is Life?* Fourth is L. Jánossy, an outstanding investigator of cosmic rays. Not shown is L. W. Pollak, a distinguished meteorologist and director of School of Cosmic Physics. All these men with exception of Pollak and Jánossy work in the School of Theoretical Physics.

cially pleasing to have a vivid one-hour discussion later, and an hour's discussion again the next day. My distinguished audience helped me in the understanding of my own lecture.

I was especially happy that my stay in Dublin gave me the opportunity to talk with Schrodinger and Heitler. Schrodinger, a Viennese brought up in the great tradition of the Austrian physicist Ludwig Boltzmann, is known as the originator of wave mechanics. His name is linked with those of Germany's Werner Heisenberg and Great Britain's P. A. M. Dirac; the trio were jointly awarded the Nobel prize in 1933 as the creators of quantum mechanics Dirac and Heisenberg were younger than Schrodinger when they wrote their great papers. They are now in their late 40s, Schrödinger in his early 60s. Theoretical physics, more than most sciences, is a young man's game; the greatest achievements in it usually come while the imagination is still youthful and unfettered. Schrödinger has done much first-class work since 1928, but none of it of such a revolutionary character as that in the years 1925-28. The same thing can be said, though perhaps to a lesser degree, about Heisenberg and Dirac.

SCHRÖDINGER is not only a great scientist, he is a most interesting and charming man—intelligent, witty, erudite. He admires Spinoza and good literature, and is himself an excellent writer. I saw him for the first time when he lectured, with spirit and artistry, in the Berlin of 1928. He was then at the peak of his fame, he occupied Max Planck's chair in theoretical physics, the greatest scientific honor in Germany. I saw him again in 1934 in Cambridge, England, when, on a Rockefeller Fellowship, I was working on the unitary field theory with Max Born, who had just left Nazi Germany. On Schrodinger's invitation, I went to visit him at Oxford and spent a delightful evening in his home. He was interested in the unitary field theory, and wrote an important, original paper on the subject. The distinctive mark of Schrödinger's genius has always been the originality of his thinking, his self-confidence and disregard for tradition. He showed a lack of political judgment, however, when he left Oxford to return to Austria in 1936. He escaped, after Hitler entered Vienna, only by a dramatic flight to Switzerland From there he went to Dublin on de Valera's invitation to become the first professor at the Institute for Advanced Studies

The Dublin Institute arranges public lectures from time to time In 1943, Schrodinger gave a series of colorful lectures which appeared five years later in book form under the title: *What Is Life?* Startling titles must disappoint anyone who looks in books for an answer to unanswerable questions. Schrodinger's book is not an exception to this rule. It deals vividly and intelligently, however, with questions that lie on the borderline between physics and biology—a field which many people believe will form the center of future research. Schrodinger says. ". . . living matter, while not eluding the 'laws of physics' as established up to date, is likely to involve 'other laws of physics' hitherto unknown, which, however, once they have been revealed, will form just as integral a part of this science as the former. . . ."

Schrödinger points out that the architecture of a gene, that is, the manner in

which atoms are put together to create the big molecules that form a living organism, is today unknown. It is, as the science writers love to say, a mystery—a word which curiously is most often used in the popularization of that most rational subject, physics. In contrast to a crystal, which represents a design that repeats itself, the big molecules that form the living organism are like an artistically woven tapestry, it is the design of the entire tapestry that matters, not the mere repetition of a theme

At the molecular level in physics disorder and chaos reign. In the macroscopic world of our measurements—the world of pendula, steam engines, electric currents—all is order. Gas obeys the laws that have been confirmed by our measurements because it is composed of a tremendous number of molecules, and the laws are based on averages. Order emerges in our macrophysical world from the disorder in the microphysical world through the laws of statistics applied to many disorderly individuals But these laws collapse and become meaningless if there are only a few molecules in the gas container. Only when it becomes colder and colder, when the temperature approaches absolute zero, only then does order reign among the molecules. It is the order of death; molecules that do not move cannot be disorderly.

Yet the living process somehow defies the rules; it organizes a group of molecules into a high degree of order. A big molecule, a single group of atoms, produces orderly events. It multiplies itself, forming an organism that lives. Even in a complicated organism, the number of such molecules is amazingly small. One cubic inch of air contains a million times more molecules than a grown-up mammal. The mechanism that governs an organism which is composed of not too great a number of molecules is not the statistical probability mechanism of ordinary physics. We shall understand the laws of living organisms only when we understand the transition order-from-order which seems to reign in biology, just as the transition order-from-disorder reigns in physics.

Schrodinger's book is not easy; it deals with difficult problems which will challenge science for a long time to come. The fact that his lectures were attended by overflowing audiences speaks well for the Dubliners.

In Dublin everyone had time to talk; no one rushed. We could and did discuss everything and nothing. And indeed it was a great relief to be back in a part of the world that appreciates leisure. Europe is a lazy man's world, which has its advantages. I learned in North America how not to be lazy—and received ulcers as a reward.

On the last day of my stay in Dublin, I visited the Institute's School of Cosmic Physics. Its director, L. W. Pollak, is a famous meteorologist. He is small, plumpish, bald and vivacious, and he talks with the ease of those who have sharpened their tongues in Continental cafés. He showed me a neatly furnished drawing room which he maintains as a shrine, from this room de Valera directed the 1916 revolt. Pollak was a professor at the German university in Prague in the 1930s, but had the foresight to leave that city just before Hitler entered it. As early as 1926, he had had the idea of introducing a punched-card system into geophysics in general and climatology in particular. He organized a climatological network in Czechoslovakia. His punched cards were sorted and tabulated by machines in Prague's statistical office. This system has now been adopted all over the world. And his dream suggestion for the creation of a world weather office is now a reality. The U. S. Weather Bureau in Washington has more than 70 million punched cards of all meteorological elements from every place in the world where observations are made. The Bureau's machines quickly digest experiences and store up information. Thus they help to predict the meteorological future by analysis of the past. A book by Pollak and V. Conrad, giving an account of this wartime development, is to be published by the Harvard University Press this fall

The Dublin Institute School of Cosmic Physics owes its existence to a short memorandum that Pollak submitted to de Valera on St. Patrick's Day, 1943. Like other professors of the Institute, Pollak speaks of deValera with great admiration. All of them feel that de Valera cared about science and scholarship in Ireland.

I TALKED with another senior professor at the School of Cosmic Physics —the cosmic-ray investigator L Jánossy. A Hungarian, with untidy black hair and tense face, he is the youngest permanent member of the Institute. Recently his large volume on cosmic radiation appeared; he complained ruefully that it was already antiquated. So rapid is the advancement in this branch of science that a book cannot remain modern during the usual time-interval between writing and printing. Indeed, the field of cosmic rays is the most fluid field of physics, and every issue of the physics journals brings important contributions, new experimental results, new speculations about the origin of these rays. This is one of the subjects that has changed our picture of the elementary bricks of matter, and we are trying now to imitate the laboratory of our universe by building apparatus that will produce particles with energies of the same order as those observed in cosmic rays.

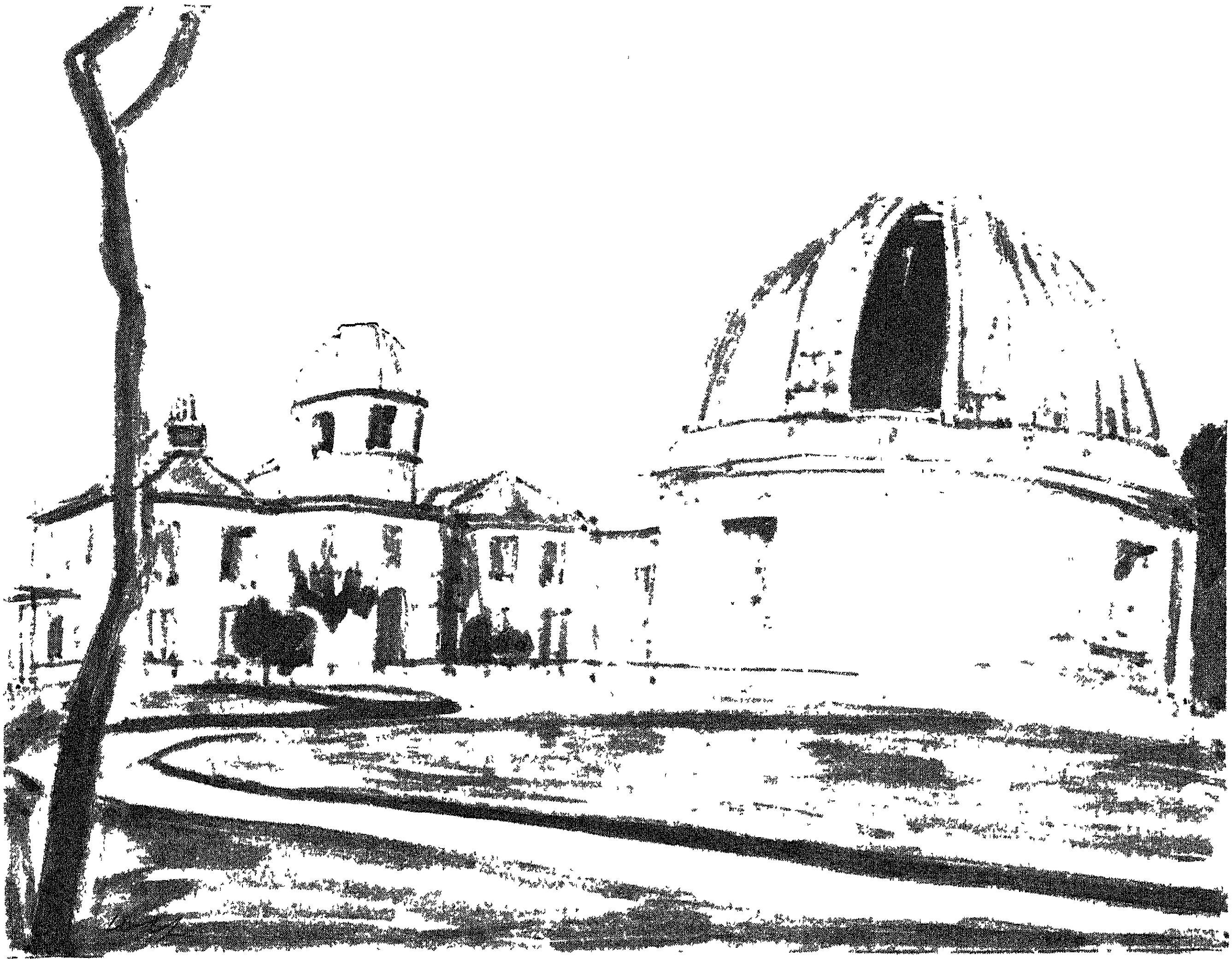
Jánossy had come to Dublin from Manchester University, one of the very best places for work on cosmic rays. When I later went to England and visited Manchester, the physicist P. M. S Blackett showed me its equipment and talked about some of the problems being investigated in cosmic radiation. Jánossy and his collaborators had investigated especially the so-called penetrating showers of mesons created by cosmic rays. The problem of the penetrating showers has also been treated theoretically by Heitler and his group at the Institute. It is an interesting example of successful collaboration between theory and experiment.

How are these mesons produced? One can simplify the present picture as follows The father of the mesons is a heavy, fast-moving neutron or proton, winging toward the earth from outer space. The mother is the nucleus of an atom in the atmosphere with which the father collides. The mother itself consists of many protons and neutrons. Therefore the fast father suffers (or rather enjoys) many independent collisions inside the nucleus. We may improve the comparison by saying that the fast particle is like a father running quickly through a harem. The mesons are the offspring of these activities. This general picture, I was told by Jánossy, is strongly confirmed by photographs from Manchester and the University of Bristol.

After my talk with Jánossy and Heitler, I came back to the Theoretical Physics Building. Professor Synge arranged an additional hour of discussion on my lecture. I was pleased to see—it was Saturday morning—that many of my listeners had returned, and again I profited much from the spirited remarks of Schrödinger, Heitler and Synge. Indeed, the discussion became so engrossing that I almost missed my plane to London.

As I left Ireland, I felt strongly how easily one can become attached to this small and beautiful country. I believe also I understood the reasons for it. Ireland is untouched by war or fears of war. The rest of the world seems far away from Dublin. It is this isolation, besides the beauty of the place and the charm of the Irish, that enchants a visitor. There is an inner desire in many scientists for such a refuge. Every scholar longs to be in a place like Oxford, Cambridge or Dublin which seems to be outside the world of trivial realities. In isolated Ireland, the Dublin Institute for Advanced Studies with its scholars, most of them fugitives from oppression, seems to be the most peaceful spot on earth. Can its isolation last for long?

Leopold Infeld is professor of applied mathematics at the University of Toronto and author, with Albert Einstein, of The Evolution of Physics.



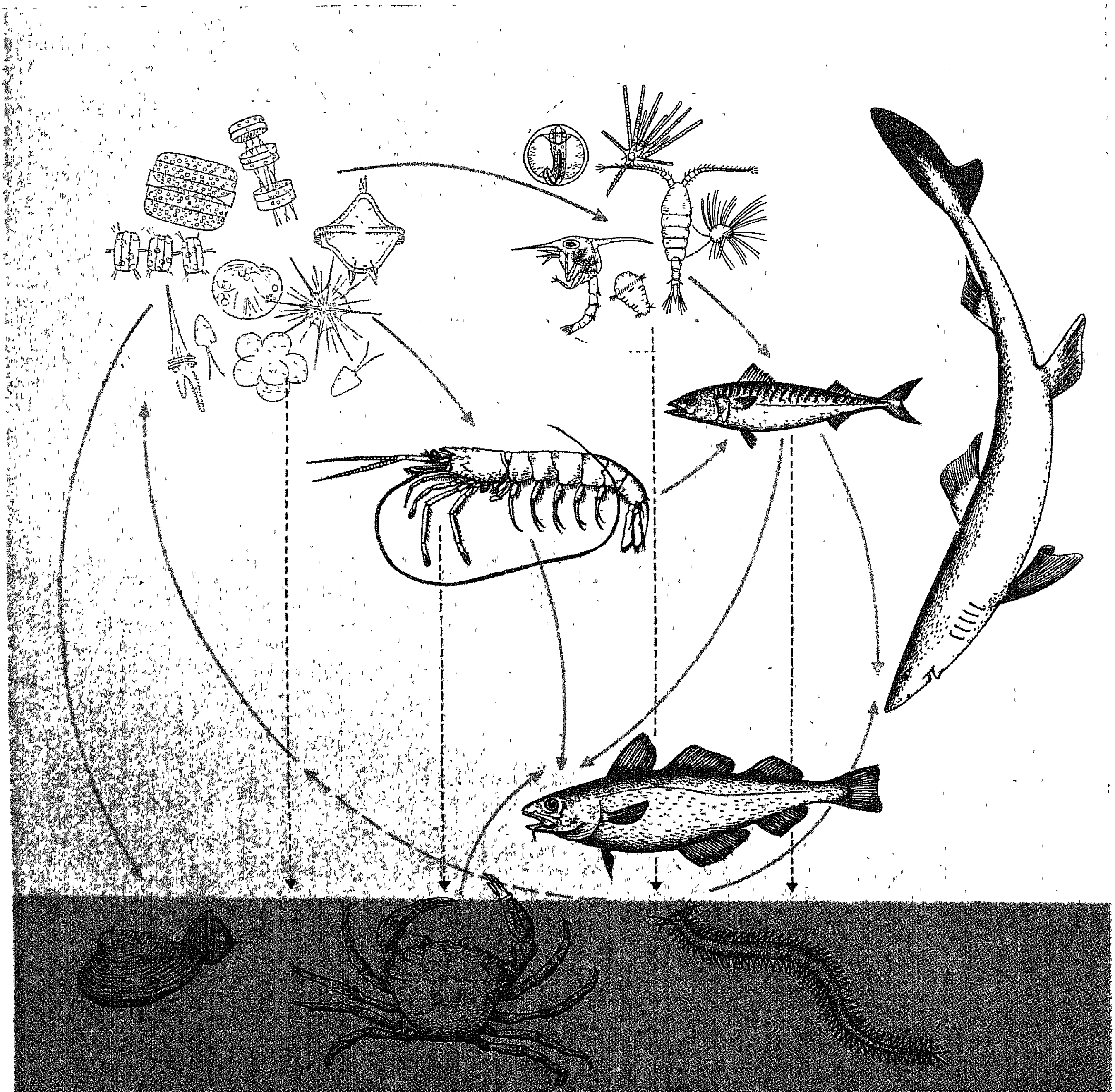
DUNSINK OBSERVATORY, at Dunsink in Dublin County, is the astronomical section of the School of Cosmic Physics. The dome at the right houses a refractor. Atop main building at left is a smaller telescope.

SCHOOL OF THEORETICAL PHYSICS stands on Dublin's Merrion Square. Across the square is the building of the School of Cosmic Physics. From the latter building Eamon de Valera directed the revolt of 1916.

Food from the Sea

Marine life outweighs terrestrial life, so it has been suggested that man turn to the oceans to ease his food shortage. A statement of the problem's biological basis

by Gordon A. Riley



GRAND CYCLE of life in the sea begins with photosynthetic phytoplankton (*upper left*). These are eaten by zooplankton and other creatures, which in turn are eaten by a chain of carnivorous fishes. Decaying biological matter sinks to the bottom, where it is eaten by bottom animals and bacteria. Nitrates and phosphates then rise.

NO one needs to be told that there is a great deal of life in the sea. Sweep the shallows with a fish net, explore the deeps in a diving bell, dip up but a cupful of ocean and examine it under the microscope—at every level the watery world swarms with a rich and varied population. But only recently have we land-inhabitants begun to get a conception of just how vast, in numbers and bulk, this population is. Even our fragmentary efforts to take a census of it indicate that the life of the sea actually surpasses that of the land. Add up the staggering total of the annual increase of living matter on *terra firma*—grass, crops, forests, jungles, bacteria, fungi, insects, snakes, snails, elephants, cattle, mice, men—all this is less than the annual organic production of the earth's oceans.

Here is a storehouse of potential food to startle the imagination. Man has hitherto taken his food almost entirely from the land; less than one per cent of what he eats comes from the sea. We would like to believe that in the immense, newly explored organic resources of the oceans lies at least part of the solution to the world's increasingly acute food problem. Lately we have heard some highly hopeful proposals and predictions—that "farming" of the sea by the use of fertilizer may multiply its yield of fish and shellfish; that even the sea's microscopic plant and animal life may be converted into food for man.

The truth is that no one at this moment can accurately assess the potential marine food resources. Large areas of the oceans are still relatively unexplored from the biological point of view. And the evidence as to the possibility of increasing our harvest from the sea is confusing, to say the least. A recent international conference of fisheries experts called attention to the fact that increased fishing effort on the major fishing grounds of the North Atlantic had not increased the catch; indeed, some biologists believe that these grounds are now being overfished. Aside from these strictly oceanographic considerations, there are technological problems and unpredictable economic factors that will have an important bearing on how much food we can feasibly get from the oceans. Yet with all these cautious reservations we are justified in taking a hopeful attitude toward the possibilities.

THE basic cycle of life is the same in the sea as on land. The hierarchy of life in the marine world, like that in the terrestrial world, is founded on green plants. They alone have the ability to convert inorganic materials into living substance, and directly or indirectly they support the whole animal population. This system by which organic matter is created by the photosynthesis of green plants, consumed and broken down by animals and recreated by plants is essential to the continued existence of any population, on land or in the sea.

At the base of the oceanic hierarchy is a vast mass of organisms so tiny that they are individually invisible. More than 99 per cent of the marine plants are microscopic, one-celled algae which have a precarious and nomadic existence. They are suspended in the surface waters of the sea and drift idly with the currents. There are hundreds of species of them in various shapes and sizes, their average diameter is about a thousandth of an inch. To the naked eye they are visible only as a greenish or brownish tinge in waters where they are abundant. Under the microscope they are resolved into great multitudes of organisms, ranging from a thousand to several million in a quart of sea water. They add up to a total of perhaps 100 pounds of plant organic matter per acre of ocean.

Associated with the plants is a great variety of small animals. Some spend their whole lives drifting in the surface waters. Others stay with the floating population only until they are grown, and then strike off on their own; examples of these are shellfish and other bottom animals. One of the most important groups of the floating animals are the copepods, tiny crustaceans about a quarter of an inch long that resemble a miniature shrimp. A copepod has a set of spines on its mouth that interlock to form a neat little sieve. The sieve strains out microscopic plants and other bits of food from the water. To help in its feeding the animal is equipped with vibrating appendages that push a flow of water through the sieve. Other plant eaters in the floating population have different kinds of filtering mechanisms, some very elaborate. Not all the animals in this population are plant eaters, however, some have grasping and biting mouth-parts and prey on the smaller animals.

The floating plant and animal society is known collectively as plankton. It provides food for a host of larger and more active creatures that live in the surface waters, including such fishes as herring and mackerel. In coastal waters and the offshore fishing banks, plankton sinking from the surface nourishes the small animals that live on or near the bottom. These in turn are the food of flounders and other ground fish.

Thus the fishes and other large animals in the sea represent the end product of a long and complicated food chain. Through a series of predations, the tiny bits of plant life are transformed into successively bigger bundles of living material. But all along the way from plants to fishes there is a continual loss of organic matter. During its growth to adulthood an animal eats many times its own weight in food. Most of the organic material it consumes is broken down to supply energy for its activity and life processes in general. It follows that the total of plant matter in the sea outweighs the animals that feed upon it, and the herbivores in turn outweigh the carnivores. Fish production is believed to be of the order of only one tenth of one per cent of plant production.

THE investigation of the amount of organic production in the sea is one of the most difficult and fascinating problems in biological oceanography. In the broadest sense it means determining the rate of production at every level in the food chain. It also means investigating the tangled skein of oceanographic and biological relationships that determine the productivity of any given region.

What makes it difficult is that marine populations are highly dynamic and unstable. They do not burgeon and wither in regular cycles as on land. The algae, known collectively as the phytoplankton, often exhibit spectacular bursts of growth of a seasonal nature, but these are hardly comparable to growing periods on land. On the contrary, the plants of the sea keep on growing to some extent the year round. At the same time the plant population suffers continual loss by animal feeding or by sinking into the depths of the ocean. So the quantity of phytoplankton present in the water at any one time may give little indication of the amount that is being produced.

The problem, then, is to find some method of separating the rates of growth and death and measuring them independently. The first method that occurred to oceanographers was to examine the water for chemical changes that might be a measure of biological activity. Some 20 years ago investigators observed that the chemical composition of sea water changes with the seasons. Phosphate, nitrate and other substances required for plant growth attain a maximum concentration in the surface waters in midwinter, when the light is too poor to favor active plant growth and when turbulence induced by winter storms brings up these chemicals from the nutrient-rich deep water. During the spring growing season, when the surface zone is well lighted, plants absorb these substances at a more rapid rate and the concentration of them in the surface water drops. By summer it is reduced to a low level. Later, as the remains of dead plankton sink into deep water, the nitrate and phosphate are liberated again.

Shortly after this discovery H. W. Harvey, L. H. N. Cooper and their co-workers at the marine laboratory at Plymouth, England, made a careful survey of the plankton and nutrients of the English Channel. They noticed that the amount of nutrients disappearing from the water during the period of intense spring growth was many times the

amount present in the plant population at any one time In other words the quantity of food vanishing down the small boy's gullet was out of all proportion to the apparently slight results achieved in growth of stature. This seemingly contradictory situation could only be explained by these assumptions. (a) the plants were actually growing very rapidly, in some cases increasing as much as 50 per cent per day, and (b) they were being eaten as fast as they grew (somewhat as the active small boy spends energy almost as fast as he ingests it).

Similar results have since been obtained in many other regions, and there is not the slightest doubt that the phytoplankton, although it appears to be comparatively small in amount, is an active producer of organic material. However, accurate estimates of plant production cannot be obtained by trying to measure the amount of nutrients consumed. This method does not take into account the fact that some nutrients are liberated in the surface layer by the death of plankton or that some are brought up to the surface from deep water by vertical turbulence. In summer (and in the tropics throughout the year) these processes approximately balance the rate of utilization of the nutrients by plants.

IN search of a more generally useful method, oceanographers turned to experimental techniques. The Norwegian investigator H. H. Gran filled bottles with sea water containing its natural plankton population, suspended them in the sea so that they would be exposed to reasonably normal conditions of light and temperature, and measured the growth of plankton that occurred during a period of a day or two. By enclosing the plankton in bottles he made sure that no nutrients would be added to the mixture. To measure the production of organic matter he divided the bottles into two groups. One group he wrapped in dark cloth; by excluding light he prevented the process of photosynthesis, and so in these bottles the plankton did not produce organic matter but only consumed it. In the lighted bottles, on the other hand, both production and consumption went on, just as in the sea. The difference in the organic content of the two sets of bottles showed the total amount of organic production.

Several hundred such experiments have now been made: by Steemann Nielsen in Danish waters, by the writer in the western Atlantic, by M. C. Sargent of the Scripps Institution of Oceanography in California coastal waters and the tropical Pacific, and by others. They are enough to draw some tentative conclusions about phytoplankton production. In most of the regions examined, the sea yields from one to three tons of dry organic matter per acre per year. This means that on the average the plant population must grow about 10 per cent per day. The most fertile areas of the ocean have approximately the same annual production as a forest. The lower limits of productivity correspond more nearly to the grass crop of a semi-arid plain Thus acre for acre, the plant production of the sea and of the land is of the same order of magnitude. But because of the larger area of the sea, its total production is almost certainly greater.

The production of animal plankton has not been studied as thoroughly as phytoplankton. The animal crop is from one tenth to one half of the plant crop. But the animal production cannot yet be estimated with a satisfactory degree of accuracy.

We are in the same situation with regard to most of the higher members of the food chain—the fishes, shellfish, and so on. The best we can do is to estimate that in the case of some commercially important species which are intensively fished the annual catch must nearly equal the annual production

Fishes and other animals at high levels of the food chain have a much slower growth rate than plankton. Several years ago Daniel Merriman and his associates on the staff of the Bingham Oceanographic Laboratory of Yale University began an intensive study of the flounder fishery off the southern New England coast. There the total fish population at any given time averages about 80 pounds per acre. From an area of roughly 200 square miles, fishermen annually take from three to six million pounds of marketable fish. Their total catch also includes an equal or larger quantity of "trash" fish that are thrown away or sometimes marketed for fish meal. Thus the total catch represents roughly 50 to 100 pounds per acre. While these figures are very rough, they suggest that the annual production of fish approximately equals the population at any one time The average phytoplankton population in this area appears to be about four times the weight of the fish. But it grows much faster; the annual phytoplankton production is over 500 times the annual fish catch. Similarly, the Woods Hole Oceanographic Institution and the U. S. Fish and Wildlife Service found that on Georges Bank, a large and important fishing area east of New England, annual fish landings ranged from seven to 33 pounds per acre, while phytoplankton production was estimated to be of the order of 1,000 times the maximum commercial catch.

THESE studies of marine productivity are a step along the way toward two goals that oceanographers have in mind. One is purely scientific—to gain an understanding of the principles that govern the existence and growth of marine plants and animals. The other is to apply this knowledge wherever possible to practical affairs.

What are the factors that control the sea's productivity? In a general way, we know some of them We know that light and temperature strongly affect the growth rate of the plants, and that temperature also influences the rate at which these plants sink to deeper levels and the rate at which animals feed on them. Currents and accompanying turbulence in the water are important if the turbulence is too great, it slaughters the surface population by carrying plants down below the zone of active growth; if the turbulence is too weak, the population again suffers because less phosphate and other food is brought up from below

The best fishing areas are generally in shallow water. There the plant population is concentrated in a small space, and the animal plankton can feed intensively and grow rapidly. There also an abundant supply of plankton falls to the bottom and nourishes the animals that live there. In deeper waters the dead plankton decomposes as it sinks, and little reaches the bottom. This is one reason why on a deep ocean bottom animal life is scanty.

During the past few years, the writer and his associates have made preliminary attempts to deal with plankton in mathematical terms. An equation can be written to predict the quantity of plankton in a given region or its seasonal changes, on the basis of the environmental characteristics of the region—light, temperature, turbulence, the depth of water, and the deep water concentration of nutrients. Precise application of the equation requires a great deal of information about the effect of environmental factors on growth rates and physiological processes in general. Unfortunately, present knowledge of these subjects is not nearly as precise and complete as might be desired. Nevertheless, in various regions where the equations have been applied, the quantities of plankton predicted by these equations agree with observations within about 25 per cent.

ALTHOUGH oceanographers are still far from satisfied with their knowledge of the life of the sea, some of their observations have already begun to bear practical fruit. The British herring fishery is an example of what may come of a few simple oceanographic observations. The herring reaches commercial size at the age of three years. It has been found that the magnitude of the catch in any year is closely correlated with the amount of phosphate that was in the water three years previously, when the herring first hatched. The implication is that the food supply during the first few months of life is a critical factor in determining survival, and a large amount of phosphate ensures abundant food.

Whatever the explanation may be, the phosphate index is a simple means of predicting the herring crop three years in advance, making it possible to plan for good years and bad.

Predictions of one kind or another will be a major function of the practical oceanographer of the future. It will be necessary also to consider controls to prevent overfishing, which endangers the production of young. This is particularly important in the case of fishes that lay a relatively small number of eggs. Even when we have solved the problems of fish conservation, however, there will remain the challenging fact that we still will be using only a tiny fraction of the total organic production of the sea.

One way to increase our harvest is by intensive oyster and clam farming These animals exist at a low level in the food chain, living on small plankton and detritus, and production is therefore relatively efficient. In the Philippines, the East Indies, China, and various other regions, considerable success has been attained in farming fishes and prawns. When shallow coastal areas are impounded and artificially fertilized, the increase in production is sometimes 20-fold. Annual yields of 4,000 pounds of fish per acre have been reported. Development and extension of fish culture in both marine and fresh waters is undoubtedly one of the best approaches toward remedying the protein deficiency of the Oriental diet.

Some people even suggest catching and using plankton. It is not an attractive food as such, but it is nutritious, and special processing might make it acceptable. But there are no large concentrations of plankton in the water at any one time, and filtering out a sizable quantity of such small creatures would require an enormous output of energy. It might be done on a limited scale, for example by utilizing tidal energy. But to harvest any considerable fraction of the plankton of the world seems as fantastic as the old dream of extracting gold from sea water. By and large we must leave the plankton to the fishes.

We can certainly learn to use the fishes more effectively, however, and catch them farther afield. There are vast fishery resources in various parts of the world that remain virtually untapped, simply because their quality or their distance from marketing centers makes them less profitable than our present commercial fisheries. Changing economic patterns and increased demand may lead to the development of such resources. Quite possibly the world's fish catch could be increased five or ten times or more.

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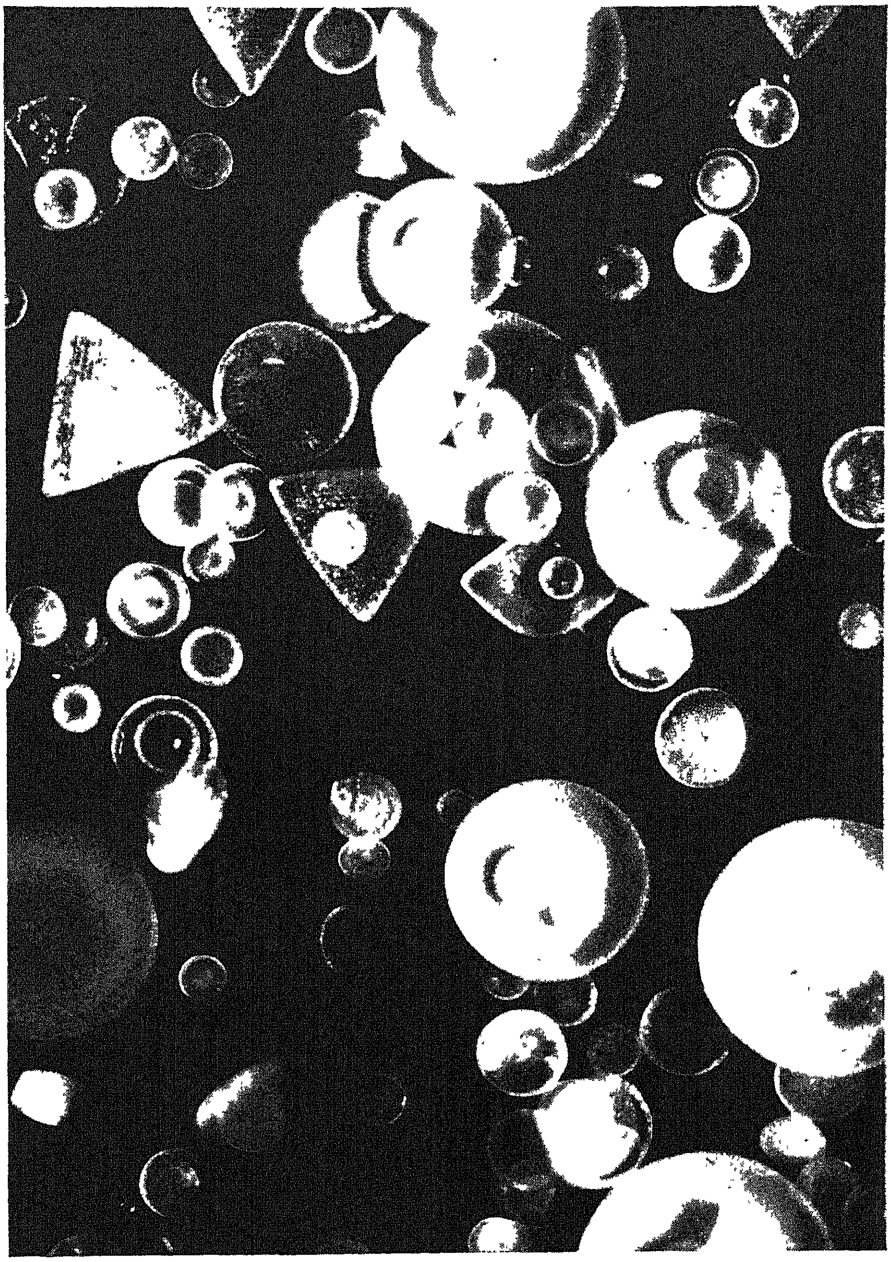
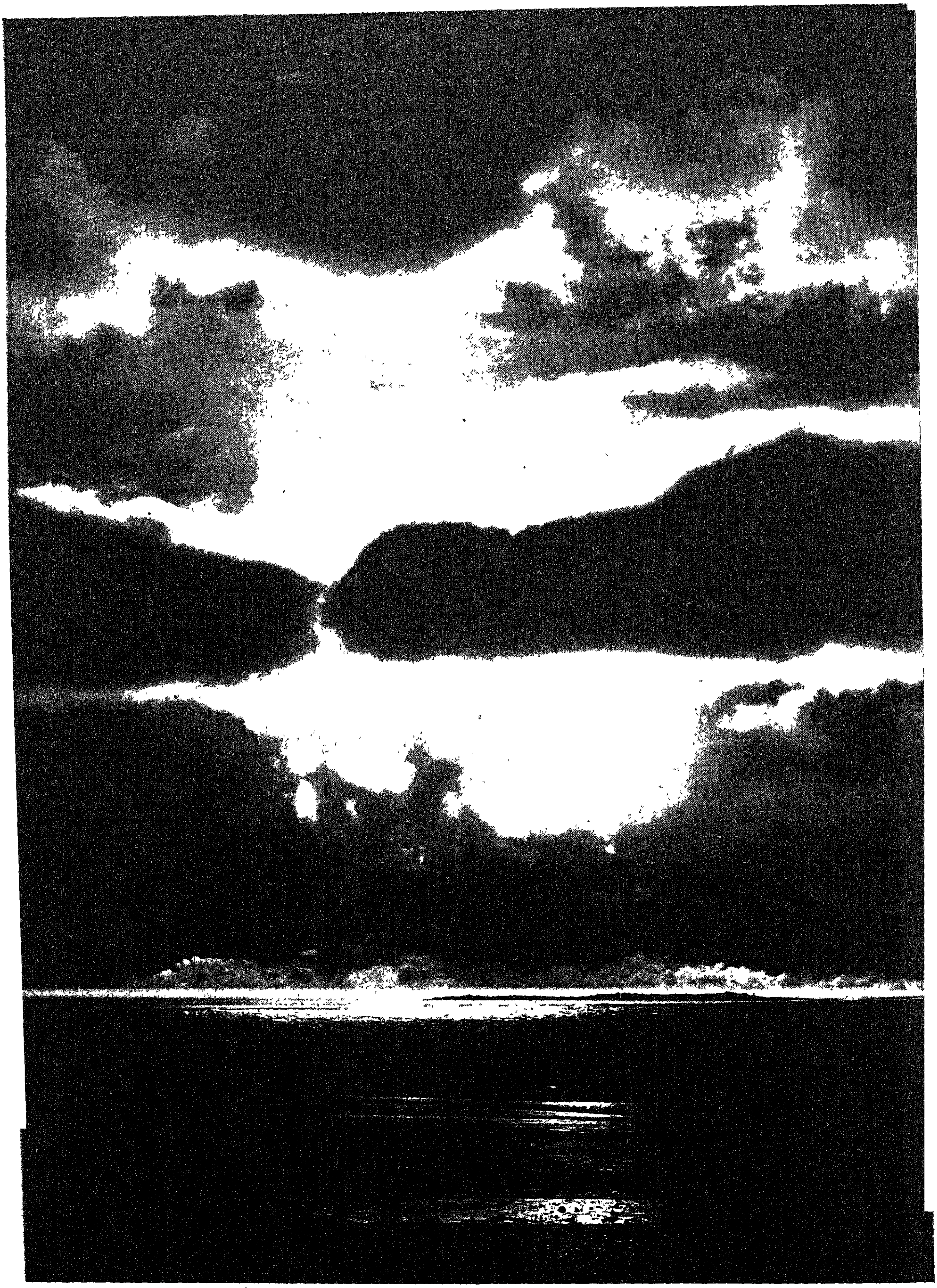


DIATOMS are a large part of the phytoplankton, the tiny plant life of the oceans. They are principally distinguished by their siliceous skeletons. When diatoms die these settle to the bottom to make up the diatomaceous earths.

COPEPODS are an important group of the zooplankton, the tiny animal life that feeds on the phytoplankton. Copepods are similar to shrimps. They have delicate spines about their mouths with which to trap the phytoplankton.



FIREBALL of one bomb rises from Eniwetok. Scale of the explosion can be roughly estimated from the palm-covered island in the center foreground. Site of the explosion is on the other side of atoll's circular lagoon.

BOMB TESTS

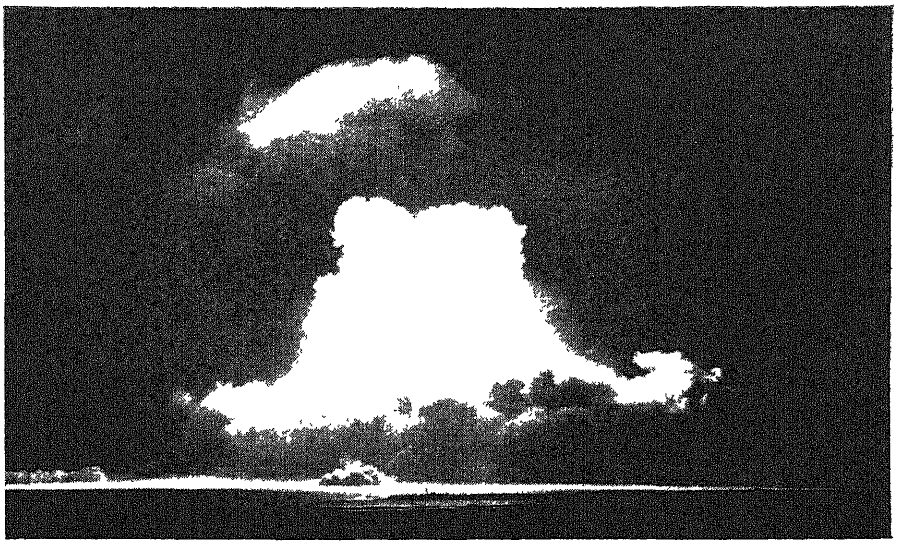
Pictures of Eniwetok experiments of 1948 are released to public

ON August 21 the Atomic Energy Commission released the first pictures of its secret tests at Eniwetok Atoll in the spring of 1948. The pictures told a little more about the tests than the AEC's guarded statement of last year. The official releases thus far reveal the following meager facts.

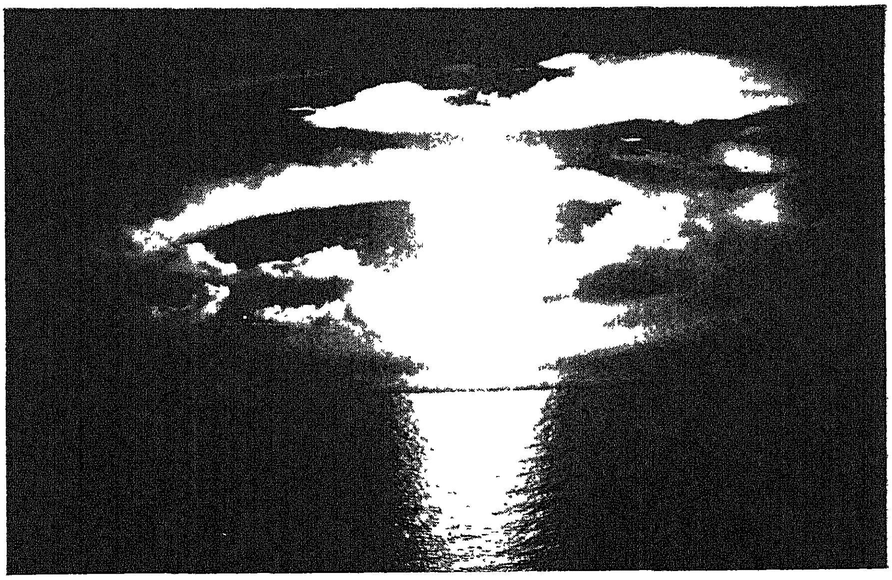
Three "atomic weapons" were tested. All three weapons were probably bombs, although the language of the releases curiously hedges this point. The photographs on these two pages obviously show bombs, but not necessarily three of them. However, Darol K. Froman, Scientific Director of the tests, has said: "The tests . . . involved a series of nuclear explosions. . . ."

All three bombs were probably set off in the air. The photograph below reveals that at least one of them was exploded on a tower The other photographs recall the air bursts at Alamogordo and Bikini. The stated purpose of the tests, moreover, was to test the efficiency of the bombs, and not such tactical measures as exploding them under water.

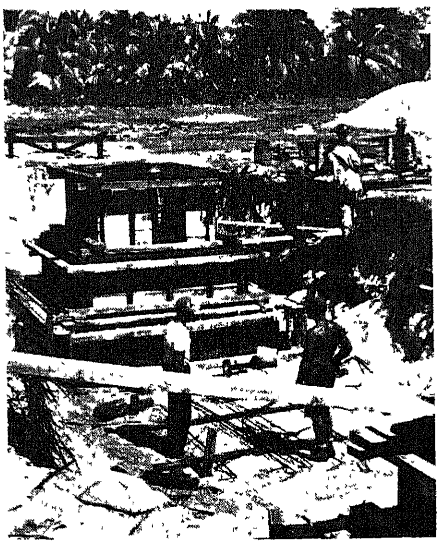
The bombs were more powerful than their predecessors. How much more so is only suggested by the photographs



EARLY STAGE of explosion in another photograph may show the test of a second bomb. Same atoll is in foreground, but pattern of cloud is different.



AERIAL VIEW of explosion was probably made at the same time as the photograph on the opposite page. Condensation ring surrounds the fireball.



TOWER from which one of the bombs was exploded is built on isle.

SHOCK WAVE, the circular marking on the water, flashes out just after the beginning of one explosion. It rushes across two islands at lower right.

LEAF SHAPE

Amateur naturalists have often observed that the leaves of one plant have many shapes. English workers have used this simple phenomenon for the study of aging in plants

by Eric Ashby

THE exciting thing about scientific research is not reviewing the results, it is making the observations. Unhappily this pleasure is no longer readily accessible to the amateur in these days of cyclotrons and infrared spectrometers; in such esoteric sciences as physics and chemistry he must be content with reading accounts of experiments he could not possibly have done himself. But in biology it is still possible for an acute observer to make interesting discoveries with no more equipment than any house and garden can provide. Indeed, we can begin to study a fundamental biological phenomenon, the aging of plants, with the simplest of observations—the sizes and shapes of leaves.

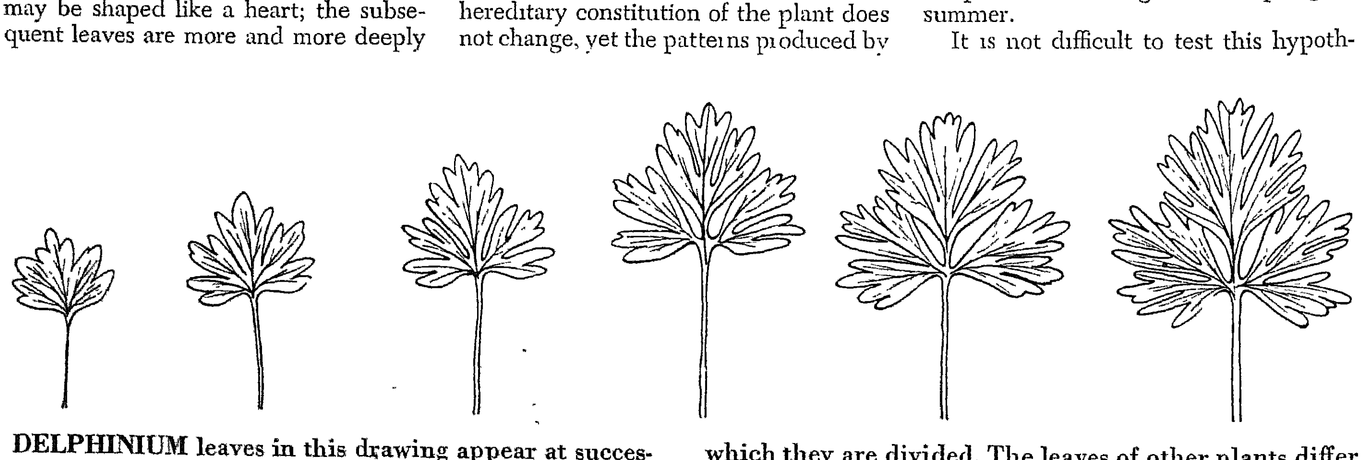
If you observe carefully the shapes of successive leaves on the stem of almost any annual plant, you will be struck by something you may not have noticed before: no two leaves on the stem are alike. Carrot, delphinium, morning-glory, hibiscus, cosmos, sugar beet—all these and most other plants show changes in shape from leaf to leaf up the stem. And the differences are not haphazard. In delphinium, for instance, there is a progressive increase in the number of segments in each succeeding leaf. If the first leaf has nine segments, the second has 12, the third 18. In morning-glory the first three or four leaves may be shaped like a heart; the subsequent leaves are more and more deeply lobed. In the English harebell the first-formed leaves are round, later-formed leaves are narrow and grasslike. In many plants the changes are so regular that they may be plotted as a graph, with leaf number along one axis and some measure of leaf shape along the other axis.

Closer inspection discloses other striking differences between one leaf and the next. Under the microscope the surface of a leaf appears as a tessellated pavement of cells, each about one 500,000th of a square inch in area. There are about four million such cells on the surface of an ordinary beet or tobacco leaf. Now the size of these cells diminishes from leaf to leaf up the stem, so that upper leaves have smaller cells than lower leaves, and they also have fewer cells—there are fewer tiles in the pavement and the tiles are smaller. This means, of course, that the upper leaves as a whole are smaller.

What is the importance of these observations on the shape and size of successive leaves up a stem? What sort of biological hypothesis can we derive from them? The observations have scientific significance for two reasons. In the first place they provide a simple quantitative example of a pattern in time: as the plant grows older the leaves it produces change in a measurable manner. The hereditary constitution of the plant does not change, yet the patterns produced by the hereditary constitution do change. In this respect an organism is similar to a piece of music, developing variations on a theme. In the second place these changes in pattern may be a way of measuring the elusive process called physiological aging. The round leaves in the common harebell, for instance, are called juvenile leaves. Under ordinary conditions adult plants do not form such leaves. But a plant kept in a state of delayed development by deep shade and high moisture, or a plant grown from a cutting, often does form juvenile leaves, even though it is an adult plant; and under these conditions flowering and old age are delayed. Is it possible, then, that leaf shape will provide some measure of the stage of development reached by a plant—not its time-age, but its physiological age? Any such possibility deserves careful attention.

FROM our initial observations, therefore, we are driven to ask how and why upper leaves on annual plants differ from lower leaves. In such an inquiry it is well to begin with the simplest hypothesis. The simplest hypothesis is that upper leaves differ from lower leaves merely because they develop later in the season, and that the consistent changes in shape and size merely reflect the changes in temperature and light from spring to summer.

It is not difficult to test this hypoth-



DELPHINIUM leaves in this drawing appear at successive levels from the bottom to the top of the plant. The leaves differ in size and in the number of segments into which they are divided. The leaves of other plants differ from one another in various ways. In each case, however, there is a regular variation in leaf shape with age.

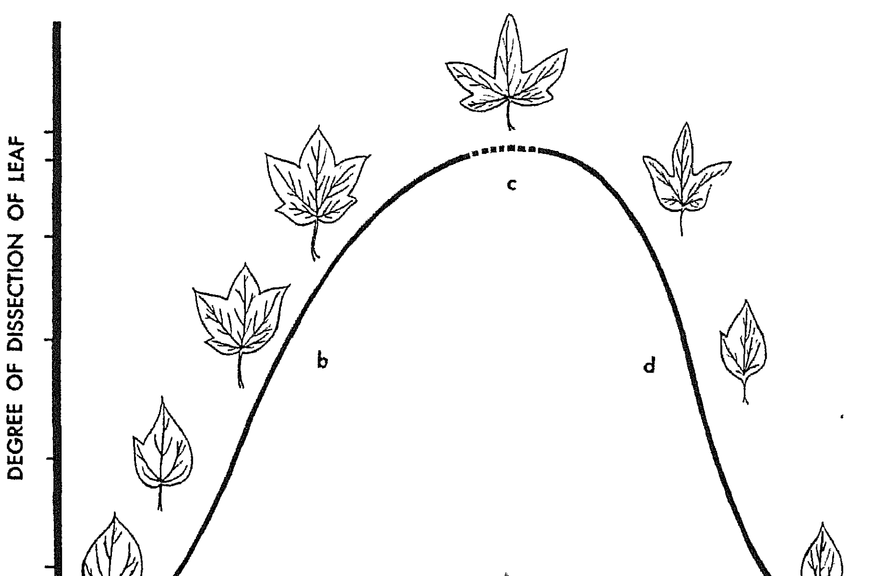
esis. If, for instance, morning-glory plants are sown in pots once a week through the spring, and all are grown side by side in the same greenhouse, then the tenth leaf of an early sowing will develop at the same time and under the same environmental conditions as, say, the second leaf of a late sowing. If the leaf shape and size are merely the product of the environment, these tenth and second leaves should be alike. Results of numerous experiments show unambiguously that this is not the case. Leaf shape and size depend mainly upon position on the plant. It is true that they are also influenced by the season, but the effects of season are quite different from the effects of the position of the leaf on the plant We are therefore obliged to reject the simplest hypothesis, and to seek an explanation of the trends in leaf shape and size in some internal change in the plant related to its physiological age.

We must note at once that the aging of a plant is quite different from that of an animal. In an animal the processes of growth occur all over the body until maturity, and the animal may then continue to live a long time even though growth has stopped. In a plant the processes of growth are localized at the growing tips of the stems. In a corn plant, for example, cells at the tip are continually dividing to form new leaves. Above the youngest leaves there always remains a zone of newly formed cells, called the meristem, from which subsequent growth will come. The manner of growth of a corn plant from its tip is, to use a farfetched analogy, rather like the growth of a knitted woolen sock from the needles at one end. It follows, therefore, that a plant is not the same age all over; its lower leaves may be three or four months old while the uppermost leaf is only a few hours old. So long as the plant is growing, new meristem cells are being formed at the tip of the stem. Thus in time-age the tip is perpetually young. But it is certainly not perpetually young in physiological age. In a young plant the meristem cells give rise to juvenile leaves, in an older plant they give rise to adult leaves and eventually to flowers. And it appears that this inexorable process of aging goes on even when the plant has a constant supply of nutrients and constant conditions of light.

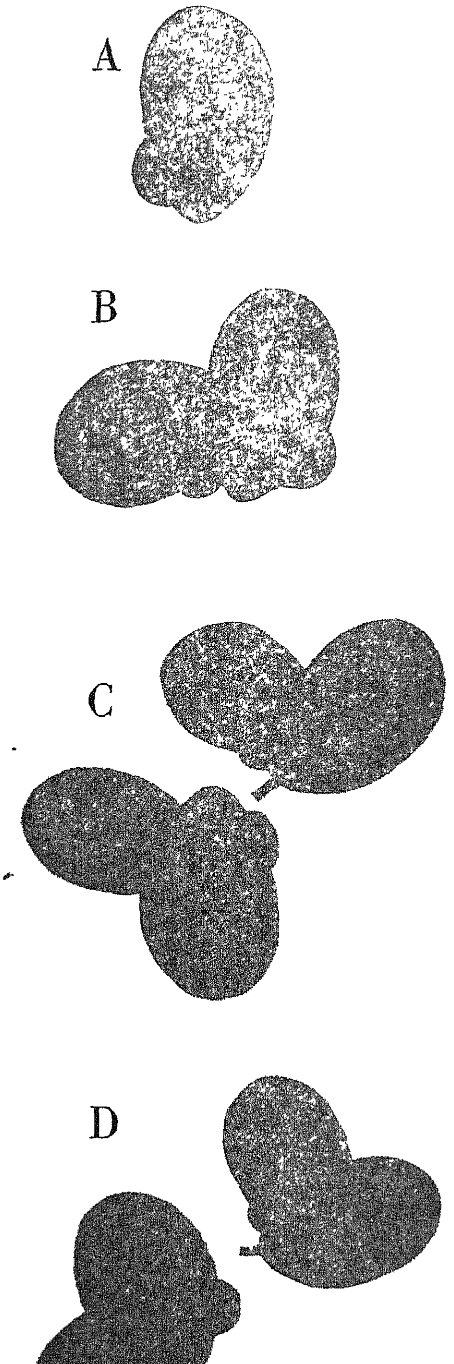
SO we meet here a central problem of biology: the problem of the cause of old age. There are encouraging signs that the anatomy and shape of leaves may be a useful measure of plant aging—and to be able to measure a phenomenon is the first step toward understanding it.

Recently at the University of Manchester we have begun to study the aging of a plant under constant environmental conditions. The plant we use is the com-

ENGLISH HAREBELL produces round leaves when it is young, long leaves when it is older. At left is normal plant with both juvenile and adult leaves. In center is plant grown in shade. At right is plant grown from cutting.



COTTON leaves have been used to measure the physiological age of the entire plant. Physiological age of a plant may differ from its time age. Plants grown under different conditions may age physiologically at different rates.



DUCKWEED is an important experimental organism in the author's laboratory. "Mother" frond (A) produces several "daughter" fronds. The latter are smaller as the plant grows.

mon floating duckweed, which can be found in almost any stagnant pond. Each leaflike frond produces a "daughter" frond from a pocket in its side; when this first daughter is fully grown, a second daughter frond is produced from a similar pocket in the other side of the parent (*see drawings at left*). By the time the second daughter is grown the first daughter frond has broken away and become a separate plant, and out of the empty pocket a third daughter appears. This is followed by a fourth daughter in the pocket formerly occupied by the second daughter. In this way a mother frond may bring forth up to five daughter fronds, after which the mother frond dies. The life expectation of a mother frond is about 45 days. The five daughter fronds produced in this time are similar to five leaves on a normal plant.

The remarkable fact is that even in the most carefully controlled artificial environment, each of the daughter fronds is smaller than the one before, so that the fourth and fifth daughters are less than half the size of the first daughter. To put it another way, the meristem cells of the mother frond are, as it were, "running down."

In terms of physiology, there are two possible explanations for the running down of a frond. The first is that the mother frond produces a growth-stimulating substance which is gradually used up, so that the fifth frond receives much less than the first frond. The second possible explanation is that the mother frond produces a growth-inhibiting substance which, as it accumulates, restricts the growth of successive daughter fronds more and more.

A simple experiment shows which of these explanations is the more likely. We cut out an immature daughter frond from its mother. If its mother supplied a stimulating substance, the separated daughter frond, deprived of this substance, should be abnormally small when it matures. If its mother supplied an inhibiting substance, the freed frond should grow abnormally large. It turns out that when such a surgical operation is performed, the excised daughter frond never grows to its normal size; it is always abnormally small. This indicates that a mother frond stimulates the growth of a daughter frond, and the reduction in size of successive daughter fronds may be due to a diminution in its supply of growth-stimulating substance.

But that is not the entire story. If it were, then successive generations in a colony of duckweed plants would become smaller and smaller and ultimately disappear. This does not happen; indeed the average size of fronds in a colony remains about the same. The reason is that the impoverished fourth or fifth daughter fronds reverse the trend and produce "granddaughter" fronds that are larger than themselves. The process of aging during the life of a frond is followed by a process of rejuvenation. Each new frond in a duckweed colony is in fact part of a cycle of aging and rejuvenation. Physiological age, unlike time-age, can be put into reverse.

This cycle appears in its most familiar form in annual plants, which "run down" and die each year but leave behind seeds whose germination is in effect a revival of youth. We see in the duckweed, however, a case of rejuvenation without seed formation.

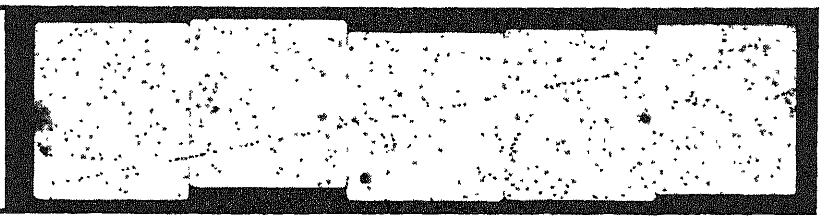
OUR data are still much too slim to justify a general theory of senescence and rejuvenescence in plants. We must be content with rough working hypotheses, most of which are unsatisfactory. The interpretation we have been considering, which is not so much a hypothesis as an attempt at diagnosis, was put forward by a Russian botanist, N. P. Krenke, who died in 1940. Krenke had observed that the leaves of some varieties of cotton change shape from place to place up the stem. Successive leaves become more and more deeply lobed, and then the process reverses and succeeding ones become less and less lobed. If lobing occurs in a comparatively early leaf, then flowering also occurs early, and *vice versa*. Krenke therefore suggested that the cycle of leaf shape in cotton is a measure of physiological age. He suggested also that when a side branch arises from a bud on the main stem, the branch exhibits some degree of rejuvenation, for it repeats the shape sequence found on the main stem. The repetition is not perfectly parallel. for instance, a side branch from a bud low on the stem has its first leaf slightly less lobed than the leaf on the main stem, while a side branch high on the stem has its first leaf slightly more lobed than the leaf on the main stem. This, however, is precisely what one would expect if leaf shape measured physiological age, and if all side branches were, like the granddaughter fronds of duckweed, physiologically younger than the main stem at the place where they arise. Since lobing in this plant at first is a sign of age and later becomes a sign of youth, we would expect the high side branches to exhibit their greater youth by developing more deeply lobed leaves.

Krenke's hypothesis does not, of course, *explain* these consistent changes; it does not even describe all types of such change. But it is a bold and provocative idea which stimulates further work, and it convinces us that the analysis of leaf shape may become a problem of great importance in biology.

Eric Ashby is professor of botany at the University of Manchester.

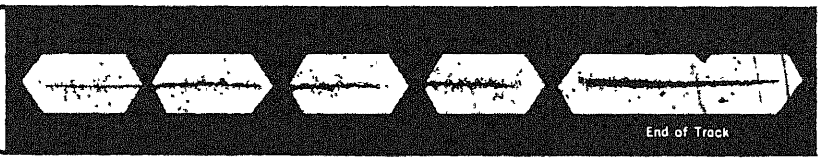
Kodak's new NTB3 Plates record high-energy particles

as light as electrons



Tracks of electrons of energy above 1 MEV.

and as heavy as iron nuclei



Sections of track of primary cosmic ray particle, identified as Fe nucleus, traveling at speed high enough for relativistic mass correction to be significant. After passing through a stack of 15 NTB3 Plates, track ends in emulsion of one of them. (*Courtesy of Dr. Bernard Peters and Dr. Helmut Bradt, University of Rochester.*)

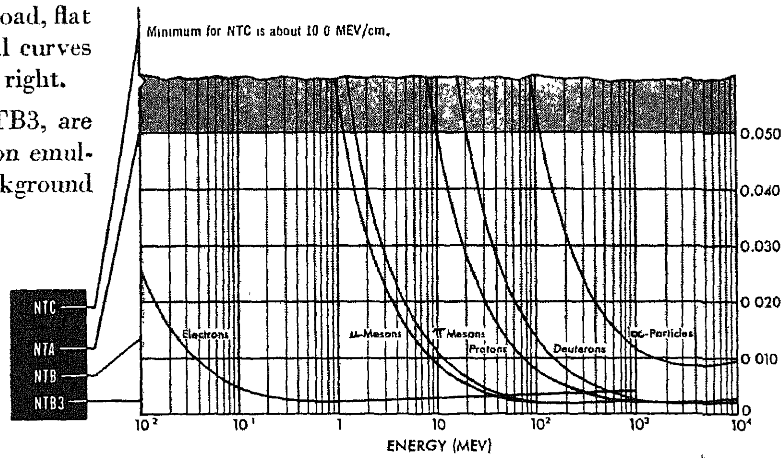
Kodak Nuclear Track Plates are opening broad avenues of progress toward understanding the nature of the physical universe.

Of the four types made, the newest and most sensitive have recorded minimum ionization phenomena. That is, Type NTB3 Plates have recorded particles of energies corresponding to the broad, flat minima through which pass the theoretical curves of energy *versus* energy-loss rate shown at right.

Kodak Nuclear Track Plates, Type NTB3, are available in 50-, 100-, 150-, and 200-micron emulsion thicknesses. Because they show background from cosmic radiation, they are shipped immediately after manufacture, should be used immediately upon receipt, and should be processed as soon after exposure as possible.

Full information about placing and shipping of orders for them will be sent upon request.

Shading shows approximate space rates of energy loss to which Kodak Nuclear Track Plates respond. Actual space rate of energy loss in emulsion is given by multiplying indicated rates by the stopping-power factor for photographic emulsions, which is about 2000.



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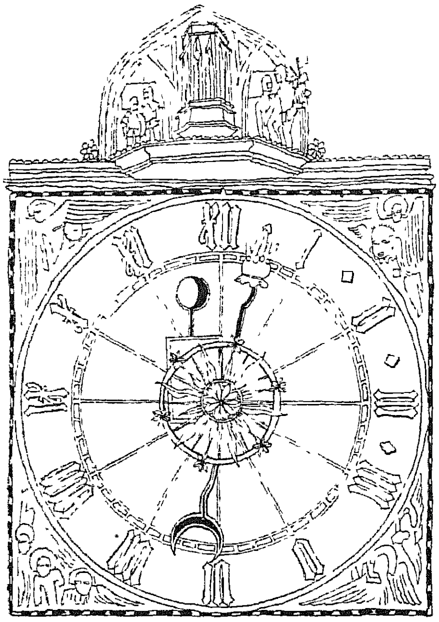
SCIENCE AND



Evolution of an Investigation

ATOM BOMB URANIUM VANISHES

(Front-page headline of an eight-column story in the New York *Daily News*, May 18, 1949.)

ATOMIC HEARINGS ENDED BY M'MAHON
Chairman of Lilienthal Inquiry Cites Lack of Quorums

(Headline in the New York *Times*, page 3, August 26, 1949.)

Thus ended the 1949 Congressional investigation of the Atomic Energy Commission, which began in a splash of page one headlines throughout the country. Its official collapse went unremarked by the New York *Daily News* and most other newspapers.

Red Dragon

HOW is an atomic bomb put together? It may be decades before this secret becomes public knowledge, but it is impossible to prevent kittens from escaping from the bag from time to time. Recently two participants in the work leading up to the bomb were permitted to tell in a newspaper interview about some preliminary experiments that take a dramatic place in the already considerable folklore of the bomb.

When physicists had worked out the theory of a uranium bomb, it became necessary to test their theory by some sort of experiment short of an explosion. They had predicted that a chunk of fissionable uranium would explode when it reached a certain critical size. It was also obvious that the critical mass must be brought together very rapidly to produce an effective explosion. In an isolated canyon near Los Alamos, a group headed by Otto R. Frisch, a refugee German physicist, set about the dangerous work of measuring the conditions approaching an atomic bomb. Their equipment, designed by Frisch, was housed in a laboratory identified by a red dragon painted on the door.

The equipment was simple One element was a block of uranium with a hole through it. Through this hole the experimenters dropped a slug of uranium. An instrument measured the increase in neutron production as the slug passed through the block. Then they dropped in a heavier slug, then a still heavier one. Gradually, using successively bigger slugs, they came closer and closer to the critical mass Finally the experimenters set off a reaction that told them what they wanted to know. During the three thousandths of a second that their heaviest slug was falling through the hole, their instruments recorded a tremendous increase in neutron production. Up to the actual explosion of the first bomb, this was the most reliable experimental evidence the physicists had that a uranium bomb really would explode.

Radiocardboard

WHEN in August, 1945, it was reported that radioactive debris from the first atomic bomb explosion in New Mexico had fogged a batch of photographic film thousands of miles away, the story seemed, even in the excitement of the time, a little too much to swallow. But the Eastman Kodak Company, which had discovered the strange coincidence of the bomb and the fogged film, took it seriously. J. H. Webb of the Kodak Research Laboratories undertook a long, painstaking job of scientific sleuthing to settle the question. He now reports, in *The Physical Review*, the convincing results of his investigation.

The film in question, a fresh batch of double-coated X-ray film that had been packed only three weeks, was found heavily spotted when it was developed. Tests of the strawboard in which it was packed showed that the strawboard was radioactive. Ordinarily this would not have been very surprising. Much of the packaging paper and cardboard manufactured in the U. S. during the war was known to possess radioactivity, due to the fact that the general paper stocks from which it was made contained radioactive paper salvaged from plants making radium instrument dials. But in this case the appearance of radioactivity was very odd; this particular strawboard had been manufactured in a special mill at Vincennes, Ind , where unusual precautions were taken to screen out radioactive raw materials Previous batches of its strawboard had shown no radioactivity.

The guilty strawboard had been made on August 6, 1945—20 days after the bomb explosion at Alamogordo. The Vincennes plant site, on the Wabash River, was about 1,000 miles from Alamogordo. Was it possible that radioactive particles from the bomb had been blown by winds all the way to the Wabash watershed and had contaminated the river water used in manufacture of the strawboard? The only way to test this hypothesis was to analyze the radiation coming from the strawboard and try to identify the atoms emitting it.

The radiation was very slight, and Webb had to devise special sensitive methods for studying it. He soon found that the strawboard emitted no appreciable alpha radiation. This ruled out the possibility that it was contaminated to any significant extent with naturally radioactive elements, such as uranium or thorium, for all such elements emit alpha rays Thus the radiating particles must be artificially radioactive atoms and the only known source that can create and disperse large numbers of such atoms is an atomic bomb.

The strawboard gave off substantial beta radiation and some gamma rays. When Webb analyzed the beta radiation, he discovered two significant facts: 1) the radiating atoms had a half-life of about 30 days, and 2) the emitted beta particles had an energy of about 600,000 electron volts. These properties virtually identified the radiating atoms, they correspond closely to those of a radioactive isotope of the element cerium, a rare earth. And this isotope, Ce-141, is one of the most prolific fission products of the atomic bomb.

So it appears that radioactive cerium from the Alamogordo bomb explosion must have rained, very thinly to be sure, over large areas of the U. S. within a radius of hundreds and possibly thousands of miles from the bomb site. This conclusion was greatly strengthened when Webb discovered that the same type of radiation as he found at Vincennes was exhibited by strawboard made in September, 1945, at a mill on the Iowa River at Tama, Iowa, hundreds of miles away.

Webb's findings plainly are no cause for alarm, for the radiation, even when concentrated in the strawboard, was far below any dangerous level. But an enterprising insurance brokerage firm, Schiff, Terhune and Co., Inc., of New York, has just turned up some pertinent facts in the

THE CITIZEN

industrial area of the radiation problem. On the basis of a large sample poll, the firm reports that 70 per cent of U. S. corporations are interested in information about insurance against radiation hazards, including atomic explosions. Virtually no such insurance is now available. The reason, says the firm's president, is that the secrecy surrounding atomic energy developments and radiation hazards makes it impossible to establish premium rates.

Atomic Shin-Plasters

NOT a few entrepreneurs have found ways to cash in on public awe (and ignorance) of atomic energy. The Food and Drug Administration reports that the quack-medicine racket has become highly radioactive. The Administration's inspectors have recently seized some interesting exhibits. One is the Zerrep Applicator, available in the regular $50 size and in a supercharged version at $100, which according to its inventor emits atomic rays that lengthen life by "expanding the hydrogen atoms" in the body. The applicator was touted to cure 67 diseases, including cancer and poliomyelitis. Other items on the FDA blacklist include atomic shin-plasters, radioactive bath salts, U-235 medicinal water, an irradiating "Vrilium Pencil" to be hung from the neck as a means of warding off illnesses.

Corner Lifted

THE first official move to make some of the vast new engineering knowledge accumulated in the atomic energy project available to U. S. industry was made last month by the Atomic Energy Commission. Following up recommendations by an Industrial Advisory Group, the Commission appointed a committee of engineers and trade publishers, headed by Sidney Kirkpatrick of the McGraw-Hill Book Company, to help in declassifying selected technological information in the field of metallurgy. This will have to do mainly with metals and alloys used for blowers, valves and other parts of vacuum pumps—a field in which the atomic energy project has made remarkable advances.

If this declassification project, announced as an experiment, works well, the Commission hopes to extend it and lift the curtain on other information of value to industry. The AEC also named a committee to study how the electric-power industry may take a more active part in its reactor program for the development of uranium as a fuel for power plants. The three-man committee is headed by Philip Sporn, president of the American Gas and Electric Service Corporation.

The A.A.A.S. Protests

A YEAR and a half ago the executive committee of the American Association for the Advancement of Science, which may be taken as the official voice of U. S. science, appointed a committee to investigate how the security restrictions of governmental agencies have affected the nation's scientists and scientific work. This Committee on the Civil Liberties of Scientists, headed by Maurice B. Visscher of the University of Minnesota, has now tendered its report. Its general conclusion is that the national "security" system, as it is operating in practice, seriously impedes scientific work and menaces the nation's long-term security. The Committee proposes a number of reforms in security procedures.

Its investigation considered the problem under three headings. 1) secrecy; 2) clearance of scientists for confidential work, especially by the Atomic Energy Commission and the National Military Establishment; and 3) Government investigations of the "loyalty" of Federal employees, particularly scientific workers. Recognizing that under present conditions some scientific work must remain secret and the reliability of persons doing such work must be investigated, the Committee holds that the area of secrecy, and the investigations, have been extended far beyond necessary and desirable limits.

As to secrecy, it recommends that restrictions on information be confined to "immediate military applications of scientific findings, rather than the findings themselves." It proposes that a sharp line be drawn between scientific knowledge, "that is, recorded observations of natural phenomena," which should not be secret, and "military plans, programs, physical locations, designs and mechanisms."

As to clearance and loyalty procedures, the Committee condemns the tendency to require elaborate clearance even for scientists who do no secret work, and the guilt-by-association pattern. The most sharply worded sections of its report have to do with the methods of investigation of the loyalty and reliability of scientists. The Committee found that the standards for judging "security risks" are ill-defined, the investigation and hearing procedures undemocratic and the decisions often arbitrary. "The effect of the excessive

precautions," it says, "is to discourage participation in research activities closely linked to the nation's well-being Scientists are increasingly reluctant to commit their personal and professional reputations to those who have brought frivolous charges against respected colleagues "

To illustrate the operation of the clearance system and of the Federal loyalty order in practice, the Committee cites a number of cases.

In one case the reliability of an Atomic Energy Commission employee was questioned because a neighbor had asserted that the employee's mother-in-law was a Communist. On investigation it turned out that the neighbor had reached this conclusion because she had heard that the FBI had been in the neighborhood making inquiries about the employee.

In another case a scientist was asked by a loyalty board whether his contribution of $250 to the United Jewish Appeal did not perhaps evidence "too much sympathy for the underdog."

Another scientist was called upon to explain her possession of an album of Paul Robeson records

A well-known scientist (Edward U. Condon) was asked whether he was not disrespectful of the older ideas in physics. He replied drily that he had always been in favor of Archimedes' principle.

The Committee notes with concern that even universities, in some cases, are making security clearance a condition for employment of scientists It recommends that its 77-page report, containing a long list of recommendations, be submitted to President Truman and be published by the A.A A S.

False Polio

IN the past five years, 1944-1948, the number of reported poliomyelitis cases in the U. S. has more than doubled over the previous five-year period. This year's total may reach 35,000, the largest on record. Do these figures represent an actual increase of such proportions in infantile paralysis? Are all the cases now being reported really polio?

Three physicians at the Yale University School of Medicine have just reported some evidence that they may not be. During the 1948 epidemic these investigators, Joseph L. Melnick, Ernest W. Shaw and Edward G. Curnen, discovered a new virus which produces symptoms like those of polio. One physician studying this virus was accidentally infected with it. He had a slight stiffness in the back and a fever that lasted for eight days, but the disease left no harmful effects. The investigators found the same virus in many supposed "polio" patients. Tests on animals showed that it was not a polio virus it failed to produce polio symptoms in polio-susceptible monkeys but did produce disease in newborn mice that were immune to polio.

The Yale workers identified the new virus in more than 50 per cent of a group of patients in Connecticut and Rhode Island whose illness had been diagnosed as polio. They also found it in many tissue samples from "polio" patients in North Carolina and Ohio. Says Melnick "It is believed that a sizable percentage of [the 28,000 reported cases of polio in the U. S in 1948] may have been falsely diagnosed as poliomyelitis and were actually attributable to this new virus. We have reason to think that this may be a fairly common disease."

All this emphasizes the great need for a simpler and more reliable test for polio than is now available. Such a test may be forthcoming by next year. A group of workers is now experimenting with a method of diagnosis which may be as effective for polio as the Wassermann test is for syphilis.

The Accident-Prone

SOME people seem to have a talent for getting into accidents. Many psychologists believe that this proneness to accidents is often a symptom of neurosis, the result of an unconscious urge to self-injury. Some psychiatrists have reported that people who have repeated accidents tend to be emotionally maladjusted. Because of the important implications of this theory, especially in industry, the U. S. Public Health Service has begun to look into it.

In an Indianapolis manufacturing plant Frank J. Harris, a P. H S. staff psychologist, carefully examined 37 often-injured workers and 33 who were rarely injured. He gave them personality tests and tests of manual skill, and studied their habits—whether they liked to gamble, how many children they had, how often they changed jobs, and so on. None of these tests, Harris now reports, showed any significant differences between the accident-prone and accident-free groups. In a talk to the American Psychological Association, Harris said

"I will hazard the statement that accident-proneness, implying a psychological predisposition to get hurt, may have been greatly overrated . . . I am not so heretical as to say that industrial accidents are accidental. However, I would leave with you the thought that the research worker might do well to concentrate less on personality and more on obvious hazards and malpractices."

Muscle Engine?

THE cyberneticists believe the day is not far off when engineers will be able to build physical machines that be-

have like biological organisms. Some biologists think it is equally legitimate to dream of building biological mechanisms that could function like physical machines. They have long amused themselves by speculating about designing biological machines that would run on chemical reactions like those in living cells, instead of on coal or electricity. They have spoken of harnessing the bioluminescence of fireflies to make lighting systems, of imitating the reactions in nerve cells to create electric power.

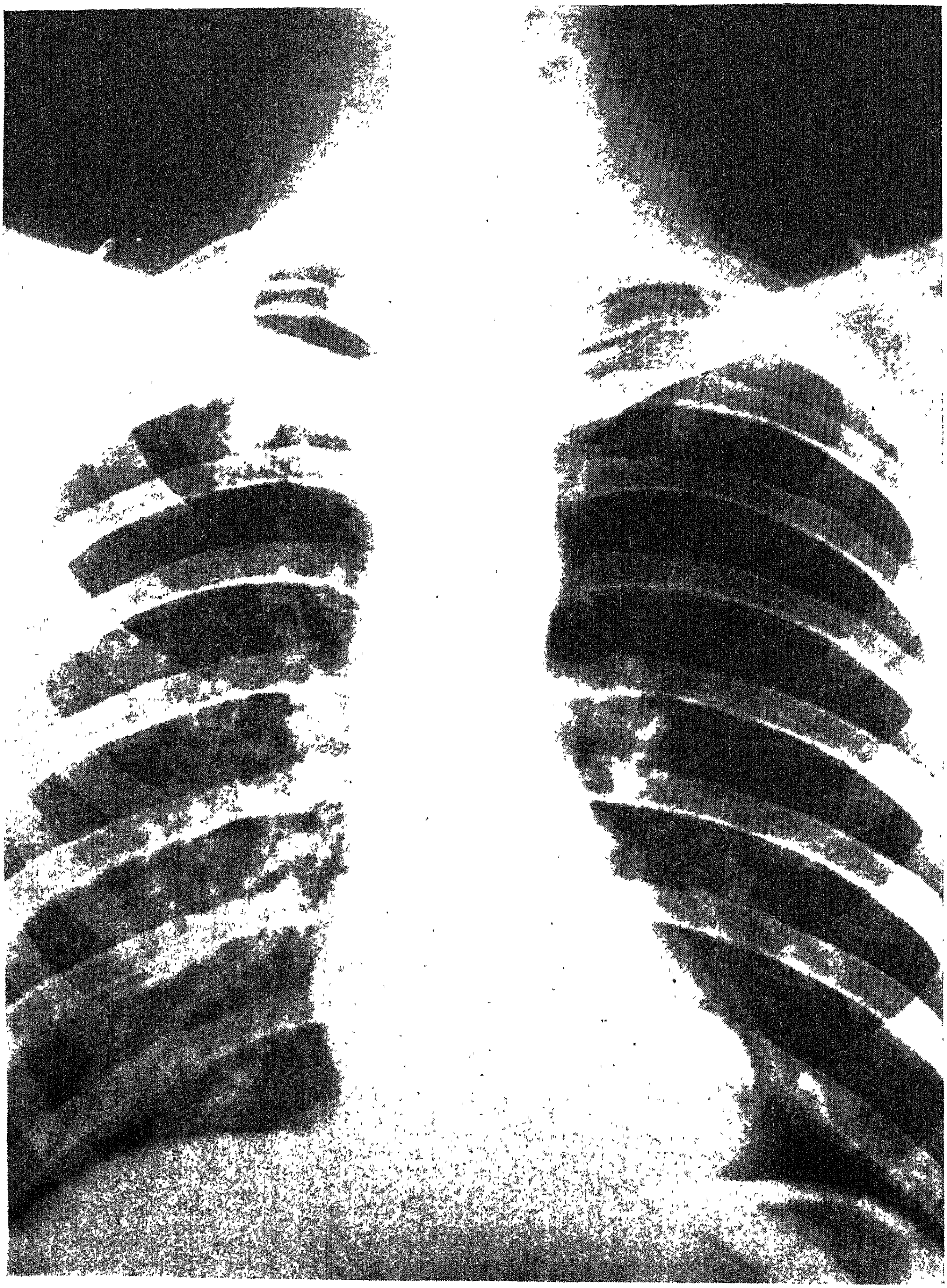
Now comes word that chemists at the Weizmann Institute in Israel have taken such a scheme a step beyond the talking stage. They are working on an engine that would operate something like a living muscle. The Israelis have developed a synthetic rubber composed, like human muscle, of long-chained, high-polymer molecules. The material expands in acid, contracts in alkali. Compounds of this kind are well known to chemists. The Institute experimenters propose to build an engine consisting of strips of this muscle-like substance immersed in water and attached to a rod. By rapidly changing the chemical balance in the water, alternately making it acid and alkaline, they hope to make the strips expand and contract rapidly, thus moving the rod back and forth like a piston. If that works, the rod will be attached to a wheel—and the biological engine will be complete. Whether it will do useful work is another question.

Thinking Machine

ENGINEERS have moved a step closer to their goal of producing a machine that will outwit man. Robert Haufe of the California Institute of Technology demonstrated at a meeting of the American Institute of Electrical Engineers a machine, containing some 30 telephone relays, that plays ticktacktoe. Its human opponent always gets the first move, and normally the machine never gets worse than a draw. It is equipped, however, with a "poor-playing" switch which changes its circuit characteristics so that a good player can beat it from time to time.

Miranda

THE fifth moon of the planet Uranus, discovered over a year ago by Gerard P. Kuiper of the McDonald and Yerkes Observatories, has finally been named. It would have been logical to name it for one of the Titans, the children of the Greek god Uranus, but the Titans' names have all been used for Saturn's moons. So Kuiper turned to the more recent mythology of Shakespeare, which has already furnished names for three Uranus moons—Oberon, Titania and Ariel. He named the small fifth moon Miranda, the "little cherub" of *The Tempest*.



X-RAY PHOTOGRAPH shows the lesions of tuberculosis in the lungs, the organs most commonly affected by the human form of the disease. Many other organs, however, may also be involved. When tuberculosis produces small tubercles throughout the body, it is called miliary tuberculosis because lesions resemble millet seeds.

TUBERCULOSIS

Although the disease claims steadily fewer victims, it is still imperfectly understood. Recently the problem has been approached by way of the tubercle bacillus itself

by René J. Dubos

LAST year 45,000 persons died of tuberculosis in the U. S. This death rate—30 per 100,000 population—is the lowest on record, and it is probable that the 1949 tuberculosis mortality will be even lower. The White Plague is no longer the most terrible affliction of civilization. Yet man is still far from the final conquest of this disease.

Tuberculosis remains the most important single cause of death in the age group 15 to 35. There are in the U S. more than 500,000 individuals of all ages who suffer, in great or small degree, from active clinical forms of the disease. Indeed, it is a striking though not widely appreciated fact that very few city dwellers escape infection with tubercle bacilli at some time or other in their lifetimes. You as an individual may have remained unaware of your infection. But the widespread occurrence of the disease is well known to the pathologist, who often finds definite tuberculous lesions in the bodies of adults reaching the autopsy table after death from other causes, such as automobile accident, suicide or old age. The immunologist also knows that many people who have never noticed tuberculosis symptoms give a positive tuberculin test, that is, a strong skin reaction to the injection of the extract of tubercle bacilli known as tuberculin—which is evidence of past or present tuberculous infection. In the words of the old physician: "Everyone has, has had, or will have a little tuberculosis."

There was a time when the relation between the tubercle bacillus and man had a grimmer aspect. As John Bunyan put it. "The captain of all [the] men of death . . . was the Consumption." A hundred years ago tuberculosis was in truth the captain of the men of death in the Western world. Its annual death rate was then of the order of 300 per 100,000 population—at least 10 times the present rate. This was true in Boston, New York, Philadelphia and Charleston, as well as in London, Paris and Berlin. Many of the most celebrated men and women of the 19th century died of tuberculosis or suffered from it: Friedrich Schiller, John Keats, Percy Bysshe Shelley, Anne, Charlotte and Emily Brontë, Frederic Chopin, Nicolò Paganini, Honoré de Balzac, Alfred de Musset, Elizabeth Browning, Henry David Thoreau, Ralph Waldo Emerson, Anton Chekhov, Marie Bashkirtsev, Robert Louis Stevenson, Cecil Rhodes. To these names should be added a long list of distinguished physicians, many of whom died of tuberculosis while engaged in the study of it. Indeed, so many of the famous children of the 19th century lived and died tuberculous that people thought there must be some tragic and mysterious relation between tuberculosis and genius. But tuberculosis affected with equal severity all intellectual and social strata and all age groups. It cast so heavy a shadow over society that it was darkly reflected in much of the literature of the Romantic Age, it was, for instance, a central theme in *La Bohème* and *La Dame aux Camélias*.

The Turn

And then the White Plague began to wane. Sometime around 1860-1870 the *tuberculosis mortality rate began to decrease* in Europe and the U. S. From a peak of approximately 400 per 100,000, it had come down to less than 200 at the beginning of the present century. Except for short, local flare-ups associated with influenza epidemics and the two world wars, it has continued steadily to decline.

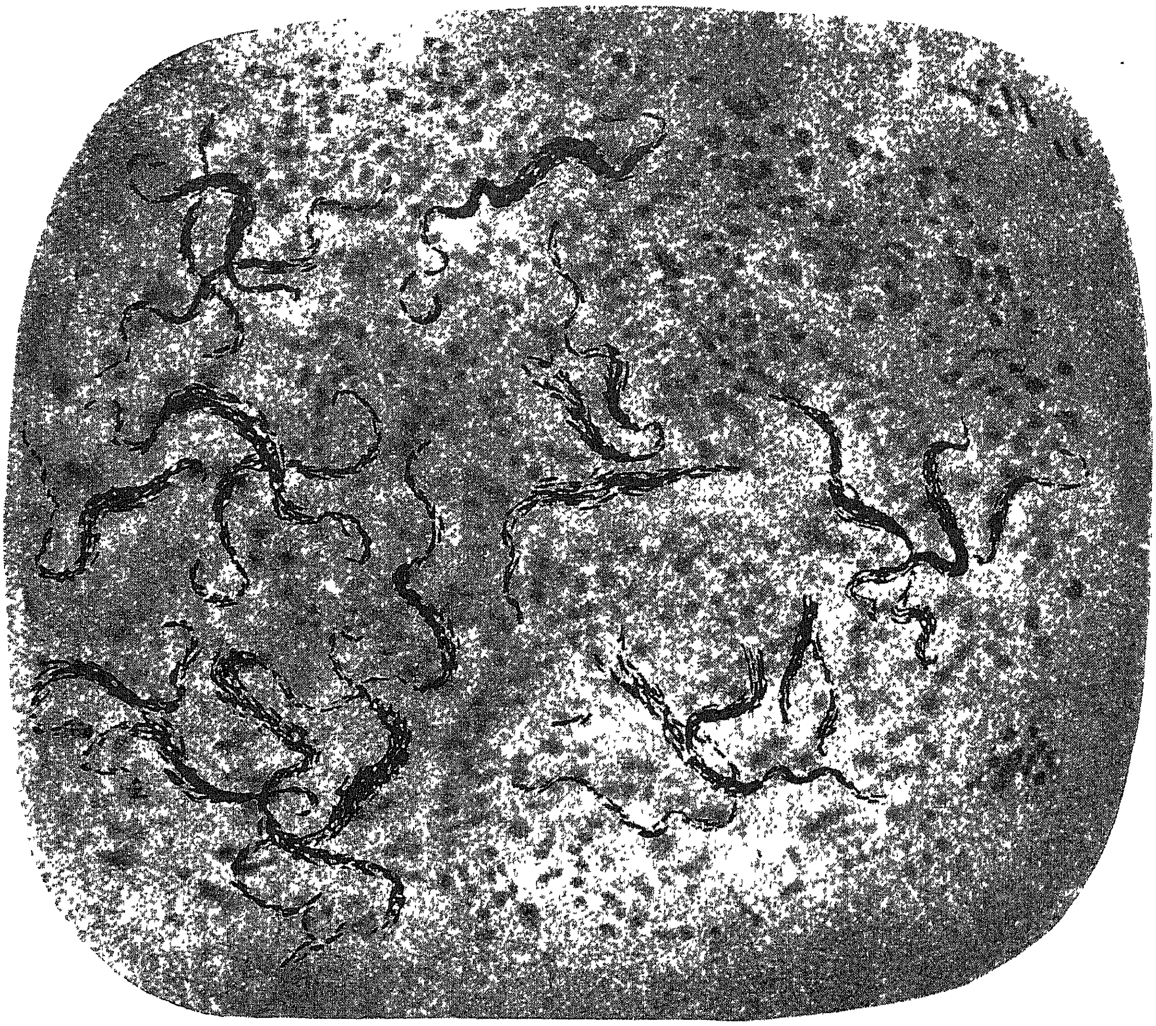
When physicians became convinced that tuberculosis was a contagious disease caused by a specific bacillus, it appeared for a while that it would be a very simple problem to eradicate the disease. Let public health officials trace the human carriers of the infection and devise techniques to prevent the transmission of bacilli from one person to another; the chain of infection could thus be broken and tuberculosis would disappear from our midst. In fact, by applying this simple principle tuberculosis has been almost entirely eliminated from the cattle of the U. S. For some 30 years the Bureau of Animal Industry of the Department of Agriculture has carried out a most effective campaign for the detection (by the tuberculin test) and elimination (by slaughtering) of tuberculous cattle

But the ruthless techniques used with cattle cannot be applied to human beings, even in the most regimented society. Too many of us would have to be slaughtered, and if all Americans infected with tubercle bacilli were to be segregated in sanatoria, few would be those allowed to remain outside the gates.

Although eradication of the tubercle bacillus from human societies is not in sight, fortunately in many places man now appears far better able than were his ancestors to accept the presence of the bacillus without too much inconvenience. The fact that tuberculosis mortality has decreased more than tenfold in the last century is a great achievement of which modern man is justly proud. But his pride is tempered by the realization that no one knows exactly how this achievement was brought about. *Tuberculosis, like leprosy* and scarlet fever, is being conquered in spite of the fact that we do not completely understand it.

The truth is that tuberculosis mortality began to decrease two decades before the tubercle bacillus was discovered; half a century before the wide adoption of such measures as early detection, segregation of patients in sanatoria and treatment by bed rest, pneumothorax and other forms of collapse therapy; almost a century before the first specific anti-tubercular drugs (streptomycin and para-amino salicylic acid) became available, and before vaccination was even considered in the Anglo-Saxon world. How, then, can one account for the downward trend that began around 1860? Many explanations have been suggested. A mere listing of a few of them will illustrate the complexity of the problem and the necessity for a many-sided approach to control of the infection.

Tuberculosis reached a very high peak in Europe and in the U. S. at the beginning of the Industrial Revolution when vast numbers of human beings began to move from the rural areas to cities where crowding, dirt and poor nutrition pre-



ROBERT KOCH, who discovered the tubercle bacillus in 1882, published this drawing of the bacilli in 1884. Koch did not know, however, that the serpentine pattern was characteristic only of virulent bacillary strains.

ALEXANDER MAXIMOV, a Russian cytologist working at the University of Chicago, published the drawing above in 1928. This strain of tubercle bacilli, he observed, exerted a destructive effect on mammalian cells.

vailed. This state of insalubrious living probably contributed to increasing the prevalence and severity of infectious diseases. Around the middle of the 19th century, reformers and public-minded citizens started to preach the virtues of pure air, pure food, pure water and less promiscuous spitting. Many hygienists claim that it was this sanitary awakening that turned the tide against tuberculosis. Others think that the chief factor was a steady increase in the abundance and variety of foodstuffs, resulting in better nourishment of the population.

Still others believe that the major factor was genetic The human strains most susceptible to tuberculosis were practically wiped out by the scourge during the 19th century As the victims often died too young to leave any progeny, there occurred a natural process of selection of those most resistant to the disease. Hence the present human stock has greater natural resistance.

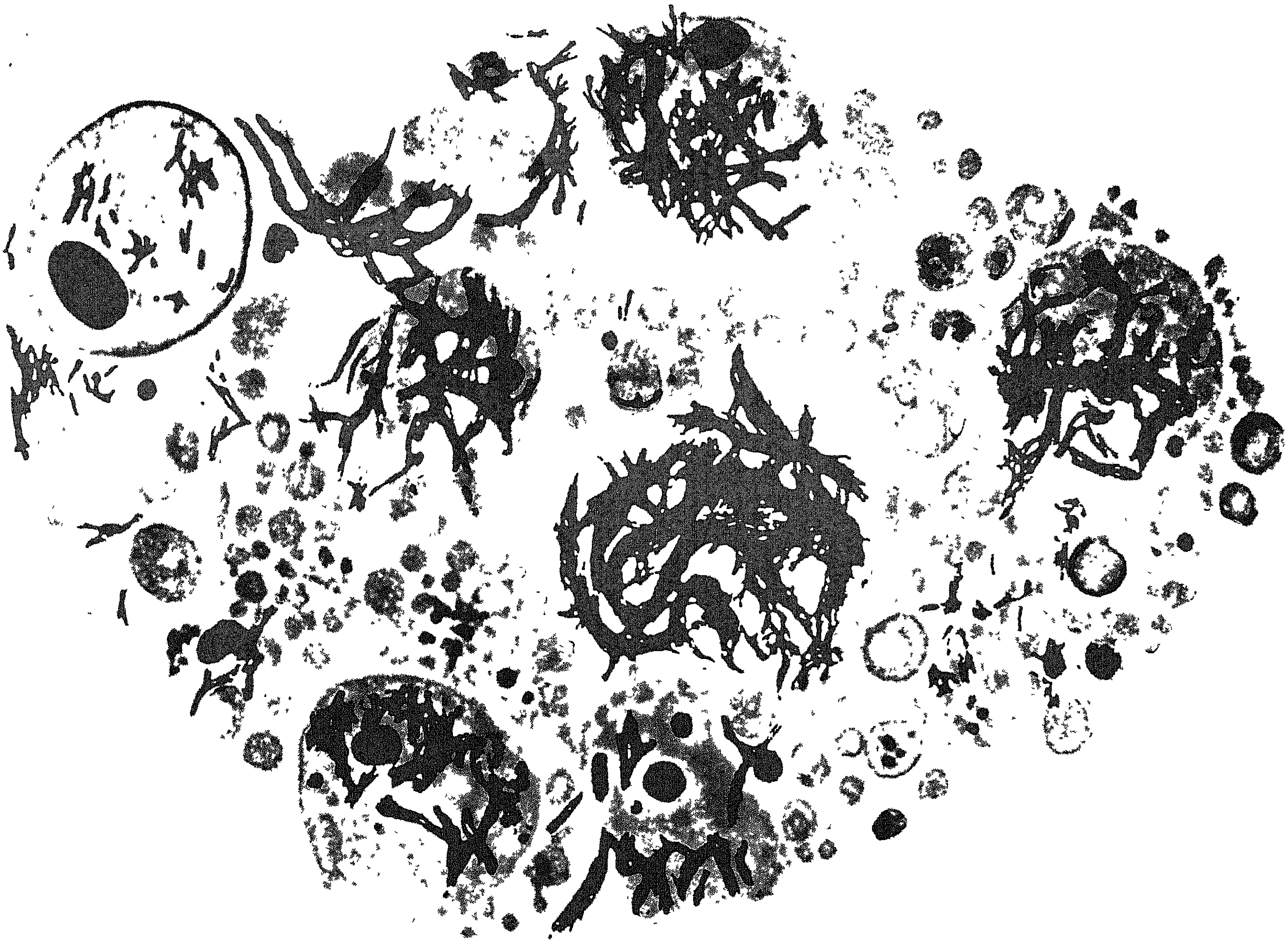
All these reasons sound plausible, but there is as yet no technique available to establish their validity or the role played by the various factors in the natural history of tuberculosis. Of one fact, however, we can be almost certain. the bacillus itself has not changed much. It is still as virulent as it was in the days of the White Plague. This is indicated by countless experiments on animals, and in a more dramatic manner by recent epidemic outbreaks of tuberculosis in certain human populations. The galloping consumption of our grandparents, now rare among us, still has the power to ravage susceptible peoples. For example, it played havoc with the Polynesian islanders when the Europeans began to establish wide contact with them In the 1914-1918 war, it was more effective than German guns in destroying the Senegalese troops brought to the French front from Occidental Africa Today it runs high among the American Indians on the reservations of Arizona and Canada. In the aftermaths of the two world wars of our century, epidemics reappeared in Europe wherever physiological misery became great. And in many countries of Latin America, in the tropical cities of India and China, and under the cold skies of Greenland, tuberculosis still reigns as the captain of the men of death

It is clear, then, that the bacillus, although a necessary condition to clinical disease, is not in itself sufficient. The microbe needs a fertile soil. It produces clinical tuberculosis only when the individual's hereditary constitution, physiological disturbances, emotional upsets, overwork and other excesses prepare the ground.

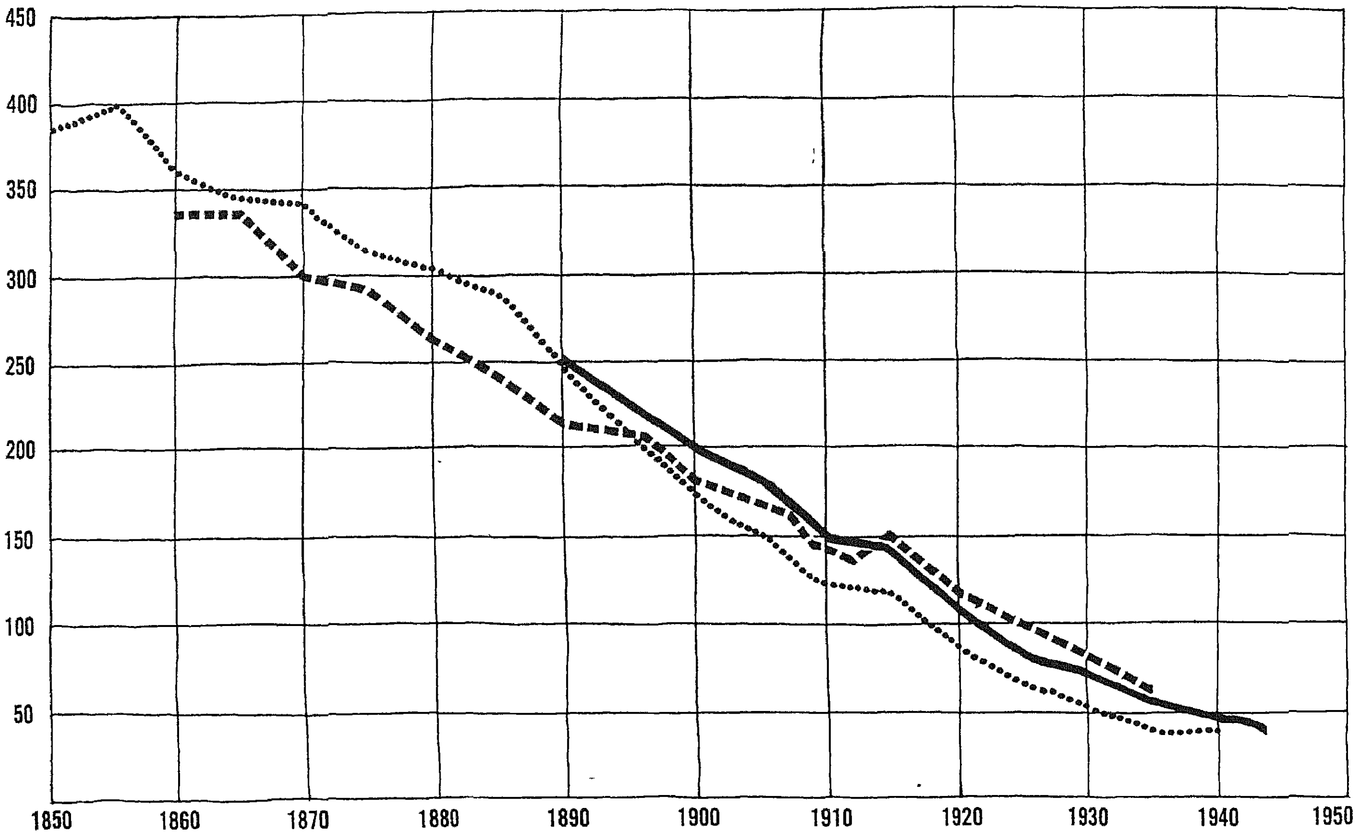
Thus there are two aspects of the disease to study the conditions in the body that enable the bacillus to produce disease, and the bacillus itself. To understand the modern work on these problems, it is useful to review the history of tuberculosis research.

Early Investigators

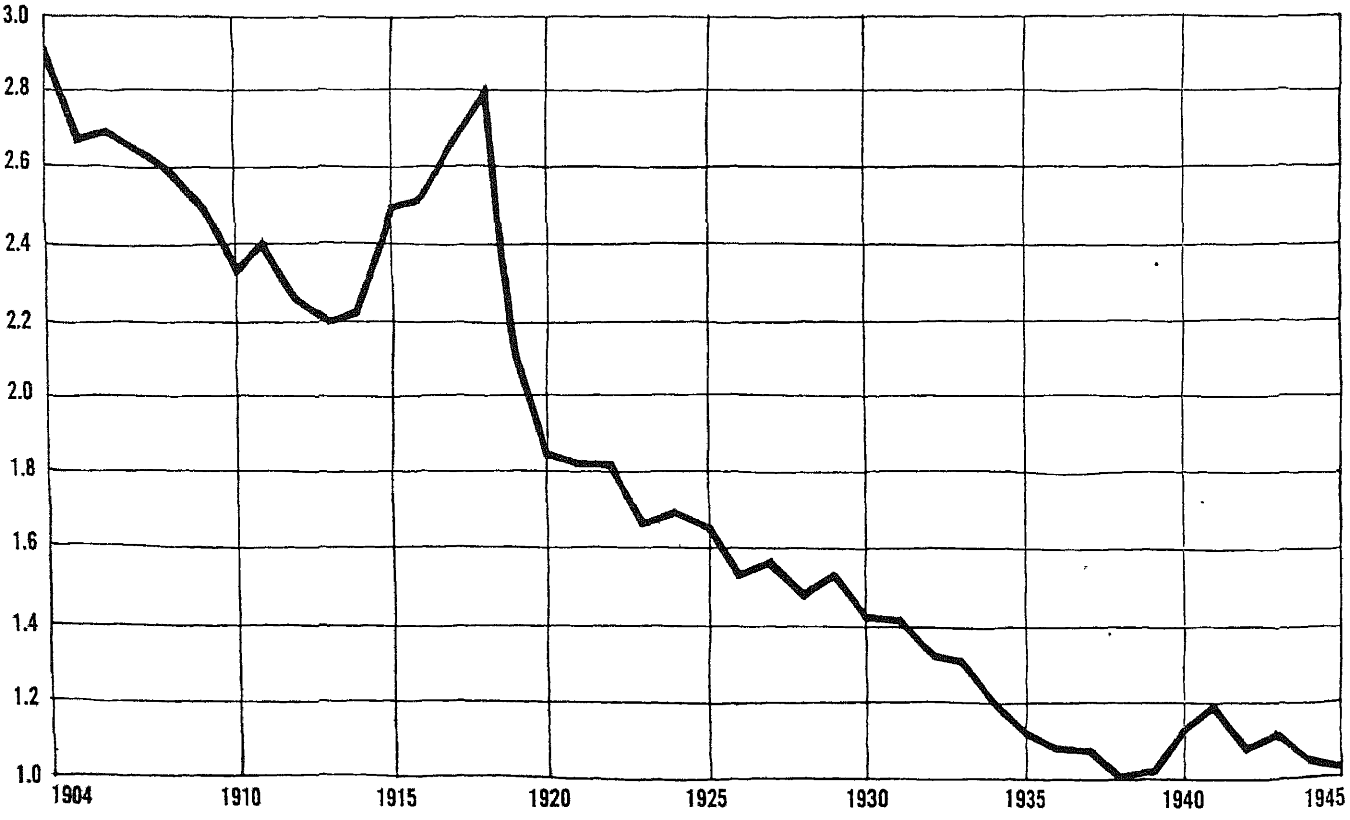
As everybody knows, the most advanced medical thinking of antiquity was codified in the writings of Hippocrates. Whether he was merely a legendary hero or a flesh-and-blood character, Hippocrates symbolizes the great Greek school of medicine which flourished on the Island of Cos during the fourth century B.C. This school was the first to teach that diseases were not visitations from capricious gods, but the results of natural causes. Hippocrates was well acquainted with consumption He de-



ANOTHER STRAIN of tubercle bacilli, Maximov showed, had little effect on cells. He failed to comment, however, on important fact that virulent bacilli formed serpentine pattern and avirulent bacilli did not.



MORTALITY RATE of tuberculosis has declined in some parts of the world since the middle of the 19th century. The three lines on this chart plot the mortality rates in the U. S., in Massachusetts and in England and Wales. The U. S. rate is indicated by a solid line; the Massachusetts rate by a dotted line; the English and Welsh rate by a broken line. The figures at bottom are years; those at left, deaths per 100,000 population.



CHILD MORTALITY RATE in England and Wales has likewise decreased since the beginning of this century. At the time of World Wars I and II, however, the rate increased sharply. The figures across the bottom of this drawing again denote years. Figures in the vertical column at left are arbitrary units based on the death rate of 1938. Figures were derived from deaths due to all forms of tuberculosis in children younger than 15.

scribed its symptoms and course with marvelous accuracy, noting furthermore that the disease appeared to be hereditary and was more common among individuals of a certain physical type and among those living in certain places. But nowhere do his writings mention the possibility that consumption might be caused by a living agent brought to the patient from the outside. The "germ" of tuberculosis, now glibly discussed by even the most uneducated layman, had no place in the medical philosophy of ancient Greece.

The Hippocratic view that consumption was an inborn disturbance of the body aggravated by environmental circumstances prevailed until the middle of the 19th century. During the long era from Hippocrates to Koch, physicians were much concerned with describing the various manifestations of the disease and the factors affecting its course and outcome, but few paid any heed to its contagiousness. In his *Phthisiologia*, published in 1689, the great English clinician Richard Morton listed "imprudent diet, overstudy, thick smoky air, and troublesome passions" among the most important causes of tuberculosis. It is not known which of these causes led him to fall victim to the disease—as his father had before him, and as his son did after him. Another student of the disease, William Stark of Birmingham, also died tuberculous, in 1771, at the age of 29, after having been the first to state clearly that many varied afflictions were in reality different aspects of tuberculosis. In France, Gaspard Bayle (1774-1816) substantiated this view by showing that early and advanced pulmonary tuberculosis were two successive stages of the same disease. It was Bayle who first used the word "miliary" to describe small tuberculous lesions—because of their resemblance to millet grains. After having studied and performed post-mortem examinations on 900 tuberculous patients, Bayle too died tuberculous, at the age of 42.

Most famous of all the students of tuberculosis who died of the disease was Bayle's close friend, the brilliant and fiery René Théophile Hyacinthe Laennec (1781-1826). In 1802 he was appointed to teach morbid anatomy in the Paris School of Medicine to replace the celebrated M. F. X. Bichat, who had just died of tuberculosis at the age of 31. Laënnec struggled with several acute attacks of the disease before he finally died of it at the age of 45. In the course of his short life this wasted, hollow-cheeked little man managed to contribute to medicine several fundamental discoveries, among them the invention of the stethoscope and its application to the diagnosis of pulmonary and cardiac diseases. By careful listening with the stethoscope Laënnec gained an uncanny

INDIVIDUAL BACILLI of tuberculosis are revealed by the electron microscope. Some investigators have suggested that the translucent rim around each bacillus is a resistant waxy capsule. Electron micrograph was made by the Radio Corporation of America. It magnifies bacilli 40,000 diameters.

INGESTED BACILLI appear as dark flecks in lighter phagocytes. Virulent tubercle bacilli immobilize these scavenging white blood cells; avirulent bacilli do not. This photomicrograph was made by Hubert Bloch at the Rockefeller Institute for Medical Research. It magnifies 2,040 diameters.

knowledge of the signs of pulmonary tuberculosis. He correlated these observations with the types of lesions found in autopsies upon patients who died. In this way Laennec established beyond doubt that many pathological conditions previously assumed to be unrelated in origin were in reality different forms of the same disease. All were characterized by the presence in the tissues of abnormal growths which he called "tubercles," whence the disease eventually got its name. Yet Laennec, despite his immense knowledge of the clinical and pathological aspects of the disease, failed to trace its origin to a parasitic agent and never was entirely convinced that it was contagious

Koch's Discovery

One of the first to insist that tuberculosis was infectious was the English epidemiologist William Budd, who stated in 1867: "The tuberculous matter itself is (or includes) the specific morbific matter of the disease, and constitutes the material by which phthisis is propagated from one person to another, and disseminated through society." At about the same time the French military surgeon Jean Antoine Villemin had also come to believe that tuberculosis was a contagious disease and that soldiers contracted it from their infected messmates Moreover, he had shown in 1865 that it was possible to make rabbits tuberculous by injecting into them tubercle material from human beings or cows. But his observations and experiments remained largely unheeded by the medical world until Robert Koch (1843-1910) brought to their support the overwhelming evidence derived from the newly developed techniques of bacteriology.

Koch was 39 when on March 24, 1882, he presented before the Physiological Society of Berlin a paper in which he demonstrated with an incredible wealth of convincing evidence that tubercles contained a peculiar small bacillus. This bacillus was very difficult to detect, it offered unusual resistance to staining by ordinary aniline dyes, and it multiplied so slowly that often weeks elapsed before its growth became evident even on the most favorable culture media. When pure cultures of the bacillus were injected into animals, they caused tubercles to form in the animals' tissues, and from these tubercles in turn bacilli could be recovered at will. The germ theory of disease was not entirely new when these discoveries were reported in 1882; Koch himself had established one of the first landmarks of the new science by cultivating the anthrax bacillus in 1876. But what gave particular glamor to his new achievement was the tremendous social importance of tuberculosis in the 19th century, and the technical difficulties involved in the detection and cultivation of its causative agent.

This paper of Koch is regarded by many medical historians as the most spectacular pronouncement in the history of medical bacteriology, but Koch's discovery left unanswered most of the problems of clinical tuberculosis. As we have already seen, the presence of the bacillus is only one factor in the development and severity of tuberculosis. Good and abundant food and thorough rest from mental worries as well as from physical effort are regarded by every physician as the most effective weapons against the disease, although it is not at all clear how physiological well-being and mental rest can increase the ability of our tissues to cope with the bacterial invader. It is in this field of research that are to be found the most important problems of tuberculosis, but unfortunately physiological science has not yet begun to deal with them. At the most it has helped in the improvement of certain surgical techniques and practices, such as therapeutic collapse of the lung. These measures, though helpful, obviously do not deal with the fundamental nature of the disease

The Bacillus

What about the other side of the problem the bacillus itself?

The most important tool for the detection of tuberculosis is X-ray photography. Several other diseases, however, show abnormalities so similar to tuberculous lesions that convincing diagnosis must finally rest on the finding of tubercle bacilli. Thus the development of techniques for the identification of the bacilli is undoubtedly one of the most useful contributions of bacteriological science to the knowledge of tuberculosis. Besides these techniques, the tuberculin test also has diagnostic value, though it serves a somewhat different purpose. As we have noted, any individual who was once infected with tubercle bacilli exhibits an increased sensitivity, or allergy, to the toxic effect of tuberculin, an extract of these bacilli. In other words, allergy to tuberculin reveals a past contact with the organism, but it does not necessarily mean that the individual still has or has had the disease in an active form. So in practice the tuberculin test is used mainly as a convenient method for ascertaining the prevalence and distribution of tuberculous infections in a given community.

The knowledge that tuberculosis is a germ disease has of course stimulated a long and industrious search for drugs to treat it. The most spectacular fruits of this search have been streptomycin and para-amino salicylic acid (PAS). These substances help in controlling the disease by interfering with the multiplication of the bacilli in the tissues. Whatever their usefulness, however, it is unlikely that these drugs, or any that may follow them, will ever constitute the final solution to the problem of tuberculosis. The ultimate goal is not to treat the patient, but rather to prevent the development of the disease.

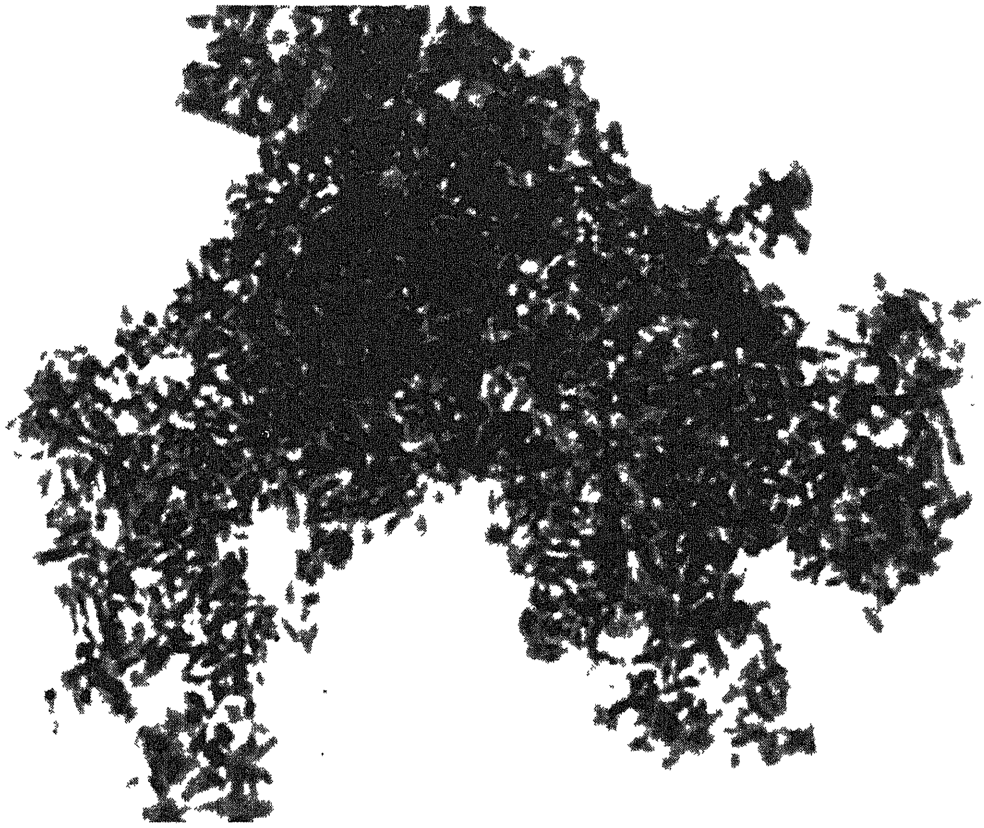
A step in this direction, though a very short and uncertain one, is the vaccine known as BCG. BCG is a weak strain of tubercle bacillus which lacks the power to cause the progressive and fatal disease but retains the ability to elicit in the individual in whom it is injected a certain level of resistance against the more virulent strains. The initials BCG stand for Bacillus of Calmette and Guérin, the names of the two French bacteriologists who isolated the strain more than 30 years ago and first advocated its use for vaccination of human beings and cattle The BCG problem is so controversial and technically so complex that it would not be advisable to discuss it in detail in this article. Let us note in passing, however, that the strain BCG illustrates the fact that tubercle bacilli may undergo a type of hereditary variation which results in loss of virulence—a property which we shall consider presently.

Although the germ theory has found so many applications, it has not thrown much light so far on the mechanism by which the tubercle bacillus produces disease. What weapons does it possess that enable it to become established in human tissues and to cause there the typical lesions of tuberculosis? This question has engaged the attention of our laboratory at the Rockefeller Institute for Medical Research during the past four years, and for that reason I shall deal with it in some detail as an example of the laboratory attack on the bacteriological aspects of the problem.

Peculiar Organisms

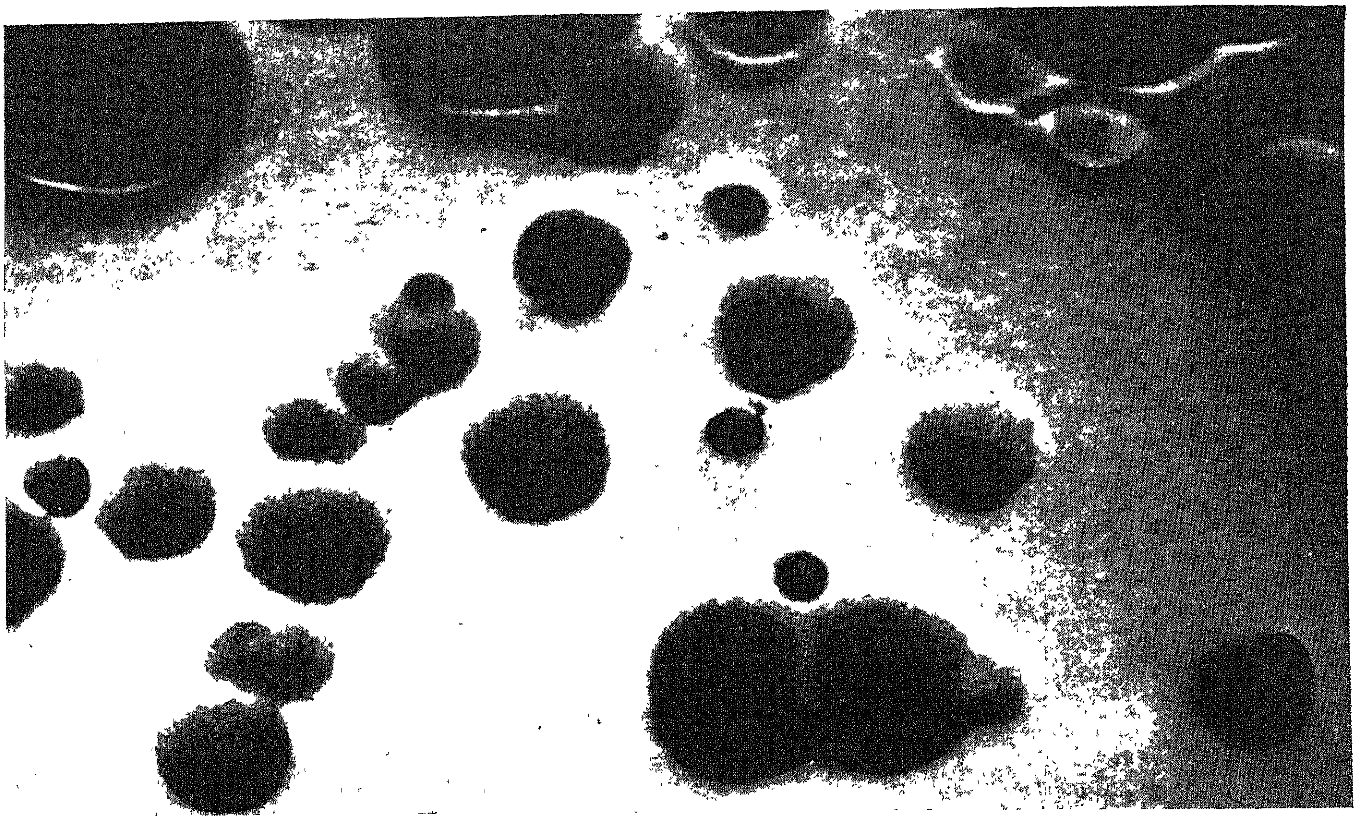
The tubercle bacilli belong to a large natural family of microorganisms commonly designated as "acid-fast" because, once they have been stained with certain aniline dyes, they are resistant to decolorization by acid treatment. These acid-fast bacilli are very widely distributed in nature; they are normally present in the human body, on objects such as rubber tubing, in certain foods such as butter, on many plants, and in soil and water. Yet of all these acid-fast microorganisms, very few species can cause disease in animals or man. How do the disease-producing species differ from their innocuous relatives?

When we decided to attack this problem, a technical difficulty at once presented itself. Unlike most other microorganisms, the tubercle bacilli are not readily wetted by water. Their surface repels water like a duck's back. Conse-

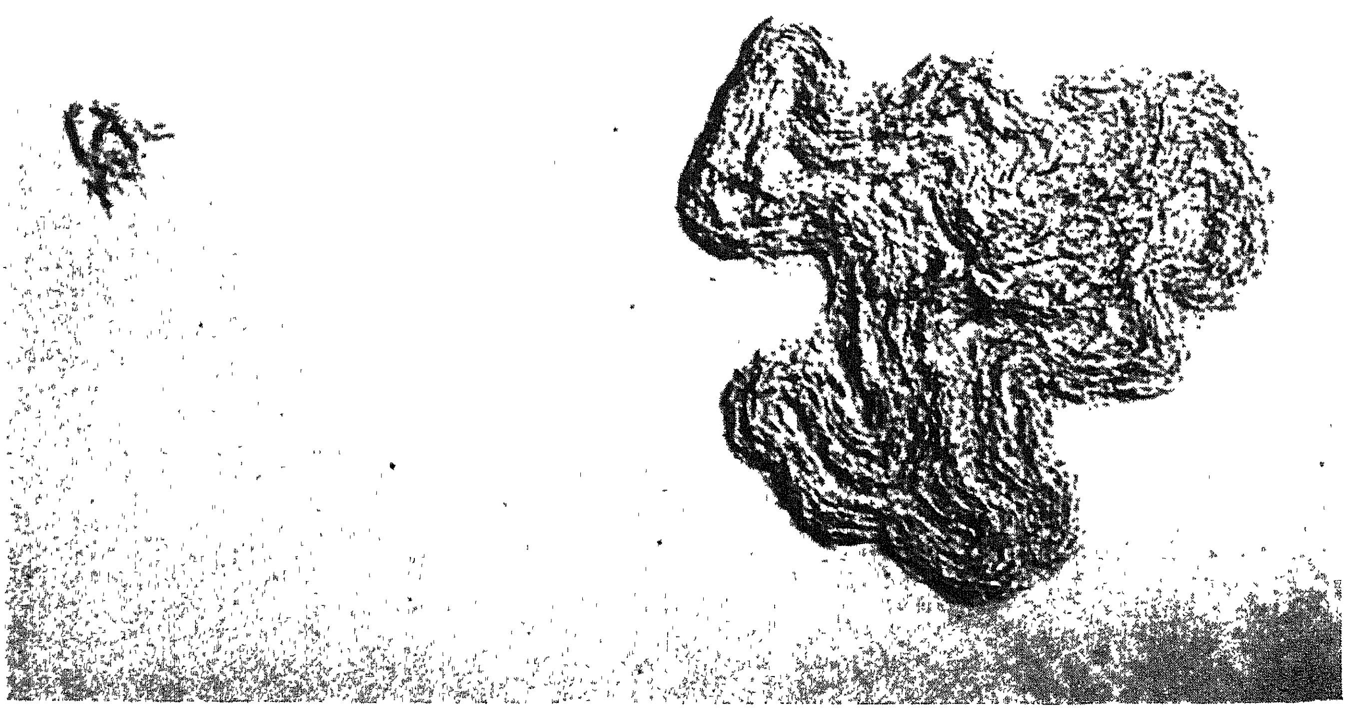


AVIRULENT BACILLI of tuberculosis in a liquid medium tend to gather in disoriented clumps. It was first suggested by the investigators of the Rockefeller Institute that this phenomenon was the result of a variation in the surface characteristics of individual avirulent bacilli. The photomicrograph was made by the bacteriologist Hubert Bloch at the Rockefeller Institute. It magnifies the clump of bacilli by 1,520 diameters.

VIRULENT BACILLI of tuberculosis form long, sinuous chains. This is apparently due to the fact that they, unlike the avirulent bacilli, adhere to each other side by side. The chains form a thin "pellicle" that covers the entire surface of their medium. Dark specks in photomicrograph are granules in individual bacilli. Photomicrograph was made by Hubert Bloch at Rockefeller Institute. It magnifies bacilli by 1,520 diameters.



AVIRULENT BACILLI form round colonies when they are grown on the surface of agar. These are much larger than the clump that appears at the top of the preceding page. The photomicrograph, made by Gardner Middlebrook at the Rockefeller Institute, enlarges them only 90 diameters. The colonies grow as the bacilli multiply; they stop growing when bacilli have used up nearby nutrients or produced an excess of toxic substances.



VIRULENT BACILLI form curiously coiled colonies when they are grown on the surface of agar in the same manner as the bacilli at the top of this page. The colonies tend to spread out rather than pile up. At the far left a young colony has sent out tendrils of the characteristic virulent chains. This photomicrograph was made by Henriette Noufflard at the Rockefeller Institute. It magnifies the colonies of tubercle bacilli 230 diameters.

quently in any culture medium using a water solution populations of tubercle bacilli have a tendency to grow in the form of clumps or thick "pellicles" consisting of millions or even billions of cells which adhere firmly to one another instead of becoming evenly dispersed throughout the medium. This peculiar mode of growth makes it difficult to prepare homogeneous bacterial suspensions and thus limits the possibility of doing quantitative work on samples of the culture. Moreover, the bacilli located in the center of the large clumps or pellicles are under physiological conditions far different from those prevailing at the periphery where air and food are readily available This results in marked variations in the bacterial population and increases the complexity of experimental work.

The answer to our problem came from chemical technology. Most people will probably remember a chemical experiment that was widely publicized in a commercial film some 10 years ago. A duck was shown floating with ease in a tank of water. Then a small amount of a detergent, or wetting agent, was dropped into the tank, and the duck's feathers immediately began to lose their water repellency and became soaked. The last stage of the experiment showed the poor bird sinking helplessly despite its frantic efforts to remain afloat. What had happened was that the detergent permitted the water to penetrate the thin coating of oil beneath the duck's feathers which traps air and keeps the bird afloat. This released the air and destroyed the duck's buoyancy.

It was this sad experience of the duck that suggested a suitable technique for cultivating the tubercle bacillus. We found that certain wetting agents—in particular polyoxyethylene esters of oleic acids and polyoxyethylene derivatives of sorbitan monooleate—when added to otherwise adequate culture media, are capable of rendering the surface of tubercle bacilli wettable by water Thus it became possible to obtain homogeneous, well-dispersed bacterial populations, instead of the large clumps or thick pellicles produced by the conventional cultivation techniques.

Virulent and Benign Strains

The solution of this technical difficulty greatly facilitated many bacteriological operations and permitted a more rapid investigation of our central problem: the mechanism of virulence. The term virulence itself is something of an abstraction; it merely means that a certain microorganism can behave as a parasite for a certain animal or plant. In order to find some suggestion as to what the concrete physicochemical basis of this property might be, we undertook a comparative study of virulent and avirulent strains of tubercle bacilli, in the hope that we could thereby recognize some specific differences correlated with the ability to cause disease.

Fortunately tubercle bacilli undergo variation like all other living things, and they can mutate in such a manner that their progeny differ in some details from the original parent strain. Thus the virulent bacilli can give rise by mutation to forms which have lost the ability to induce disease, it is almost certain, for example, that the BCG strain originated from such a mutation.

It has long been known that the virulent and avirulent variants of tubercle bacilli do not behave in the same way toward the cells of animal tissues Some 20 years ago the Russian cytologist Alexander Maximov, then working in Chicago, observed that the virulent bacilli exerted a destructive effect on animal cells growing in the test tube, whereas the avirulent bacilli failed to cause any obvious damage Does this mean that the virulent forms liberate some peculiar substance that is toxic to the tissues? That would be a natural conclusion, for as everyone knows this is precisely what happens in certain common disorders; for example, in diphtheria and tetanus the damage is done by powerful poisons, or toxins, which are released into the body by the corresponding bacilli.

In the case of tuberculosis, we have a potentially poisonous substance, namely, tuberculin, to which, as already mentioned, human tissues become sensitive. Tuberculin is a protein fraction of the tubercle bacillus. But it was found that tuberculin is produced by the avirulent as well as the virulent bacilli, and both forms are capable of sensitizing the body to its toxic effect. Tuberculin, therefore, cannot be the *primary* cause of virulence, although it certainly plays an important part in the manifestations of the disease.

During the past two years there has come to light a type of subtle action of virulent tubercle bacilli which is not exhibited by the avirulent forms. Like most microorganisms, tubercle bacilli—virulent as well as avirulent—are readily ingested by the devouring white blood cells known as phagocytes. Under normal conditions these phagocytes move about actively, especially when placed on certain types of surfaces such as plasma clots. Two years ago the Swiss bacteriologist Hubert Bloch began at the Rockefeller Institute a study of the behavior of phagocytes which had ingested tubercle bacilli. His experiments, later continued in Basel and at the New York City Public Health Research Institute, where he is now working, showed that phagocytes which have engulfed avirulent bacilli continue to move about at the normal rate, whereas those that have taken up the virulent bacilli immediately become motionless. These observations, since confirmed and extended at the Rockefeller Institute by Samuel P. Martin and Cynthia H. Pierce, provide the first clue to a direct physiological inhibitory effect exerted by the virulent bacilli on normal cells

The Serpentine Pattern

Comparison of the virulent and avirulent bacilli has also revealed striking differences in their appearance. Much of the pioneer work in this field was done by William Steenken of the Trudeau Sanatorium Laboratory at Saranac Lake Like many other workers in tuberculosis, Steenken became interested in the disease because he himself had contracted it. Although untrained in bacteriology or other medical sciences, he began to take part in the activities of the Trudeau Sanatorium Laboratory as soon as he recovered his health, and he has continued ever since to observe new and curious facts concerning tubercle bacilli.

Steenken noticed that when the nonvirulent variants are allowed to multiply in ordinary liquid media, they tend to accumulate in the form of isolated floating islands, which coalesce slowly as growth proceeds. The virulent bacilli, on the contrary, tend to spread rapidly over the whole surface, covering it with a thin veil of growth. These observations have been much extended at the Rockefeller Institute by Gardner Middlebrook, another victim of the disease. He showed that the contrasting modes of growth are the expression of variant types of forces holding the bacilli together in the course of their multiplication. Under normal conditions, the avirulent mutants grow in the form of shapeless clumps, whereas the virulent bacilli adhere to each other sidewise, a fact which gives to their growth a highly characteristic, oriented, serpentine pattern. Interestingly enough, this serpentine pattern of growth was strikingly visible in some of the very first microscopic pictures of the virulent bacillus, obtained by Koch in 1882. Maximov, the Russian investigator whose tissue-culture studies we have already mentioned, also noticed this difference in the appearance of the virulent and avirulent strains Yet no one happened to attach any particular significance to it.

There is as yet no precise knowledge of the nature of the forces which cause the virulent bacilli to orient themselves in the direction of their long axis. It has been observed, however, that the bacilli tend to lose their characteristic orientation and to separate into individual cells when they are cultivated in a medium containing wetting agents. This suggests that the orientation of the virulent bacilli may be due to the fact that they possess a special water-repellent substance which is distributed over their surface in such a way that the bacilli can adhere

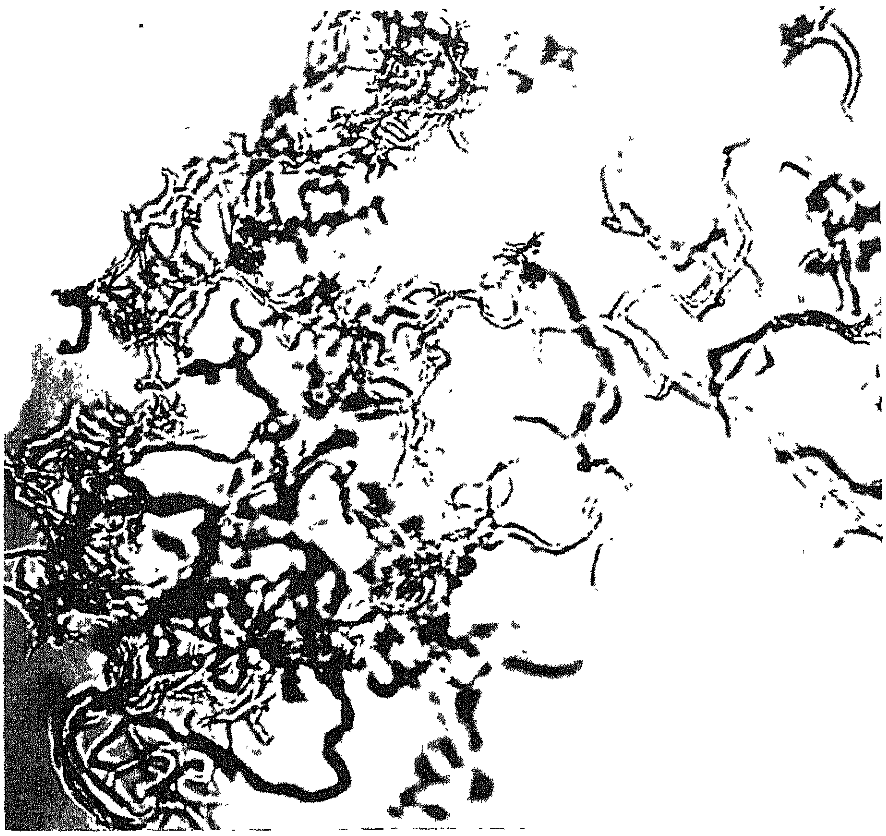
to one another only in a certain peculiar pattern

A Question of Metabolism?

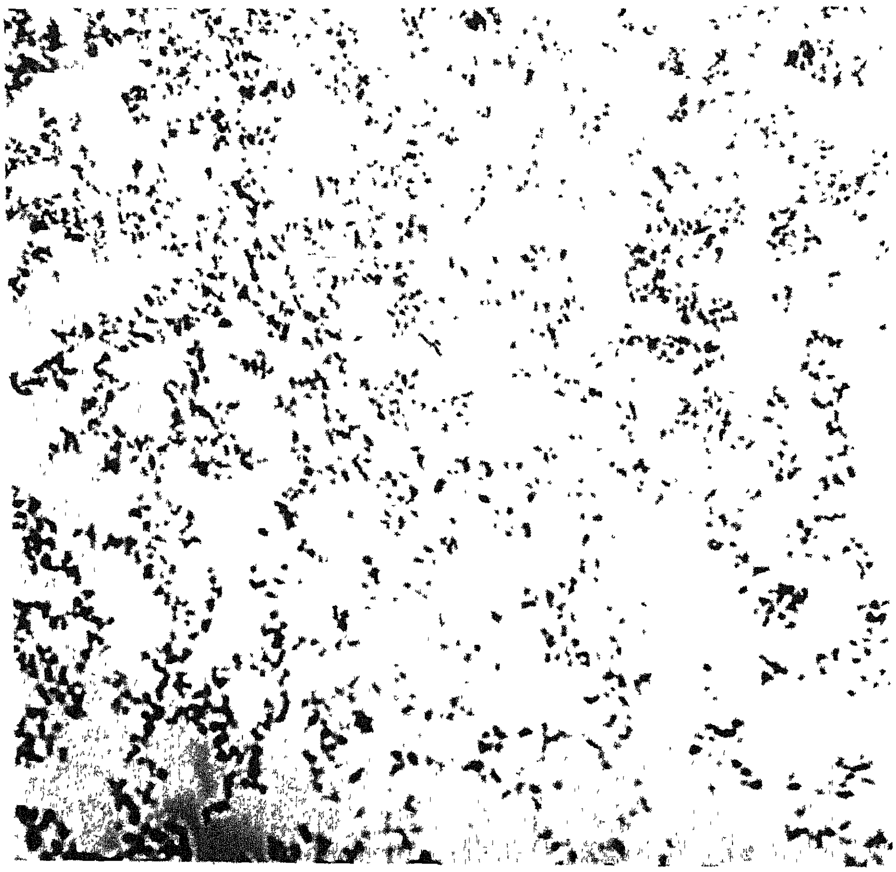
The virulent bacilli possess several other physicochemical characteristics not usually found in their completely avirulent counterparts. Thus we have recently observed that they have the ability to bind to themselves neutral red (as well as other basic dyes) in the form of its bright red salt. This occurs even when the dye is added to the bacilli in extremely alkaline media, under which conditions the dye ordinarily would become yellow. And indeed it remains yellow and unbound when exposed to microorganisms other than the virulent tubercle bacilli. This shows that the tubercle organisms possess some unusual structural characteristics which differentiate them from other living cells.

The dye bound to the virulent tubercle bacilli can readily be dislodged from them by minute concentrations of certain basic groups (ammonium ions and aliphatic amines). It is of particular interest that these same aliphatic amines, when used in concentrations adequate to prevent the binding of neutral red, can neutralize the power of the virulent bacilli to inhibit the movement of blood phagocytes that have engulfed them. Since amines are present in tissue and body fluids, here is a vague hint that substances normally produced by the body during metabolism may be able to counteract at least a part of the physiological effect exerted by the bacilli on the tissue cells. If this is true, it might open a new approach to the study of how human beings' susceptibility or resistance to infection is affected by their metabolic characteristics.

Little by little, other differences between the virulent bacilli and their variant, benign forms are being unveiled. Needless to say, it is possible, indeed likely, that many of these differences bear no relation to virulence. Nevertheless, it appears legitimate to hope that this comparative approach may lead to the identification of the peculiar structures or properties that permit the tubercle bacilli to establish themselves, multiply and cause damage in the tissues of the body. There is intellectual satisfaction in thus elucidating the intimate mechanism through which a microscopic organism can behave as a parasite, causing disease and death. Beyond this lies the long-range hope that the investigation may help someday in formulating a more rational plan of attack against the "captain of all the men of death."

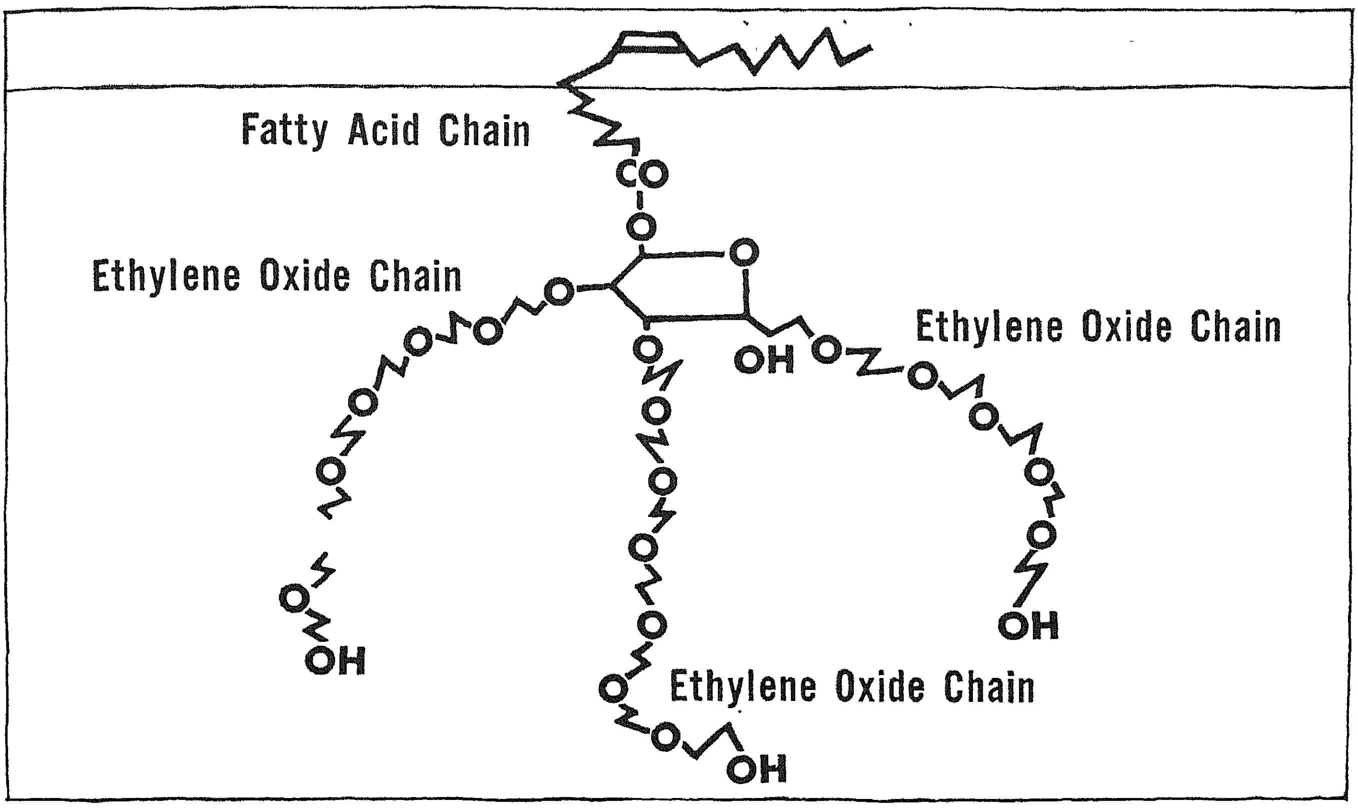


BEFORE wetting agent was increased to more than .05 per cent, virulent tubercle bacilli formed their usual corded colonies. This experiment was performed by Vernon Knight of the Cornell University Medical College.

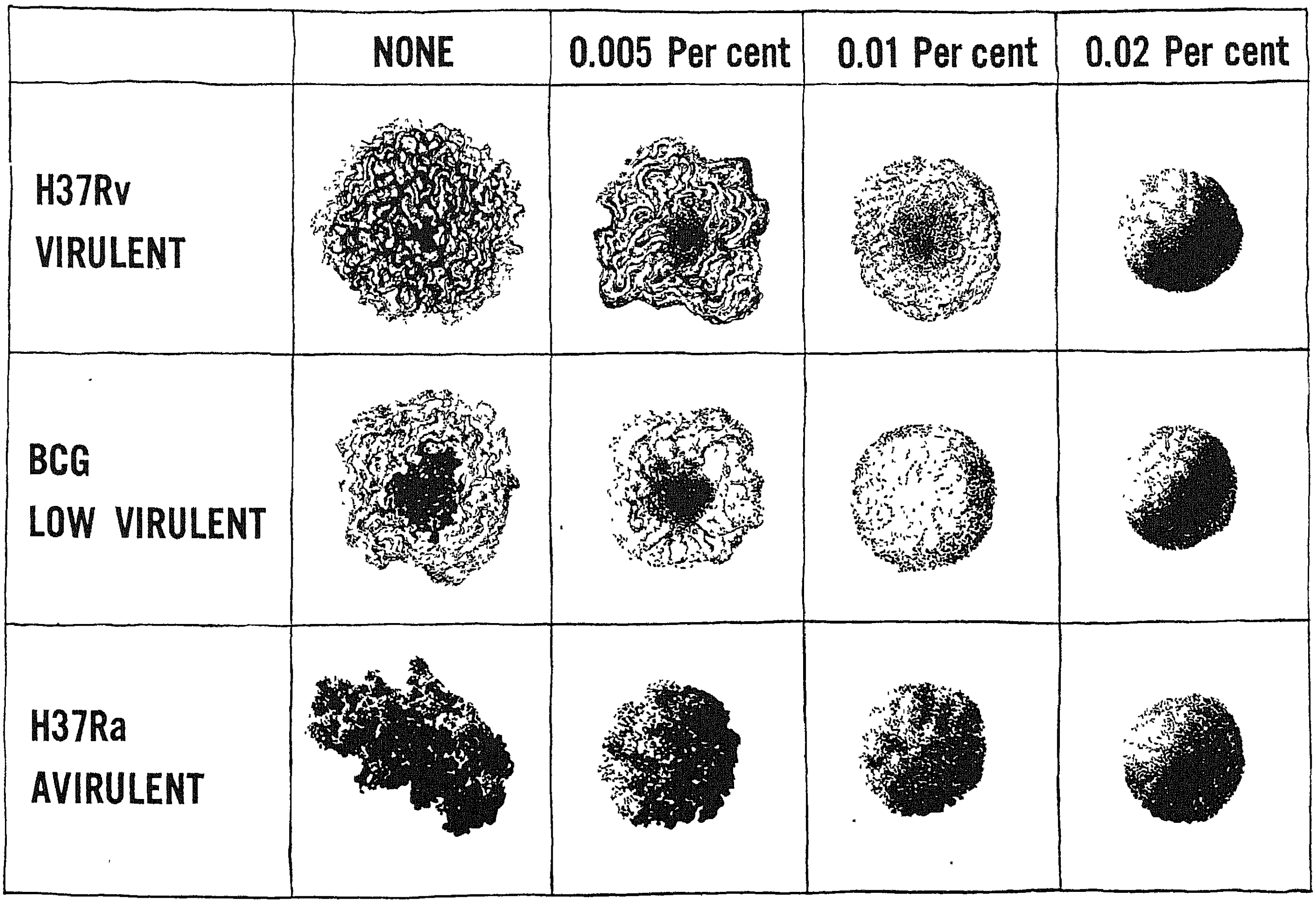


AFTER wetting agent was increased to .8 per cent, colonies were dispersed into their individual bacilli. This result supported the thesis that the virulent bacilli are characterized by water-repellent surfaces that stick together.

René J. Dubos is a member of the Rockefeller Institute for Medical Research.



WETTING AGENT MOLECULE probably causes dispersion of virulent bacilli by this mechanism. Hydrophobic (water-repelling) fatty acid chain is attracted to bacillus' hydrophobic surface (*gray*). Hydrophilic (water-attracting) ethylene oxide chains are repelled. The bacillus is thereby coated with hydrophilic chains.



WETTING AGENT TABLE shows the effect of one agent on colonies such as those that appear on page 38. Increasing the percentage of wetting agent causes virulent colony in top row to assume shape of avirulent colony. This supports other evidence that virulence of bacilli is associated with their surface characteristics.

DOUBLE STARS

The large numbers and various types of these companions in space are a problem to astronomy. The author's theory relates them to the evolution of both stars and planets

by Otto Struve

TO the naked eye each star in the sky looks like a solitary island, shining in lonely grandeur in an ocean of space. But on closer inspection with a telescope we can sometimes see, like a lookout on a ship approaching a distant shore, that what seemed to be a single island is actually a pair or even a cluster of islands. Indeed, composite stars appear to be almost more the rule than the exception. In our own neighborhood of the Milky Way, at least half of the stars are double or multiple. A famous example is Sirius, a double luminary consisting of a hot blue star and a slightly cooler and less massive companion that revolves around the primary star in a period of 50 years. As seen from the earth, these two companions at times are separated by two seconds of arc, about six ten-thousandths of a degree—a distance that can readily be measured with a large telescope.

Few double stars, or binaries, as they are called, are so widely spaced; most of them are coupled so closely that even when photographed with telescopes of the highest resolving power they still appear to be single stars. Yet we know, just as surely as if we could see them, that they are actually double. One way of detecting binaries is by observing the eclipse of one member of a pair by the other. We can observe such an eclipse, of course, only when the plane of the common orbit in which the two stars revolve coincides with our line of sight; in other words, when we see it edge on. Since the planes of the vast number of binary orbits in space are tilted at random, some of the orbits are bound to be edgewise to us.

Perhaps the best-known eclipsing binary is Algol, also known as the Demon Star or Beta Persei. Every three days Beta Persei dims to about one third of its normal brightness, and this phase, evidently an eclipse, lasts for about nine hours. Half a cycle later it dims again for an interval of nine hours, but this time the diminution of light is only slight. Thus the system apparently consists of two stars, one much hotter and more brilliant than the other. It also appears that when the cooler star is in front, it does not completely eclipse the brilliant one.

There is a second method for detecting binaries which permits us to discover the more numerous pairs that do not eclipse each other. If we look at a pair of stars revolving in a common orbit whose plane is tilted at an angle to the line of sight other than a right angle, one partner of the pair approaches us while the other recedes. We can discover this relative motion, even without seeing the separate stars, by observing a Doppler effect in the spectra of the light from the two stars. As is well known, the motion of an approaching or receding star produces a slight shift or displacement of the starlight's spectral lines from their normal position—this is the Doppler effect. In the case of a double star, there are two spectra, one superimposed on the other. At times the spectral lines are split into narrow pairs. Such a pair, consisting of two lines displaced in opposite directions, can mean only that the light is coming from a double source, one moving toward us and the other away.

During the past 50 years approximately 1,000 double stars have been discovered by means of the spectrograph, and for more than 500 of these, investigators have plotted accurate velocity curves from which can be derived the shapes of their orbits. If the velocity curve is a pure sine curve, the orbit is circular. If the curve is not symmetrical, we know that the orbit is an ellipse. From the character and amount of the asymmetry, we can determine the shape or elongation of the ellipse and the direction of its long axis.

THE discovery of the great frequency of binary stars is one of the most intriguing in modern astronomy. How do they originate, and what part do they play in cosmic evolution? This problem has interested astronomers for many years. We shall here consider it anew in the light of some recent work and new theories on stellar evolution.

The first fact that struck early investigators was the close juxtaposition of many of the pairs. It can be shown that in systems like Beta Persei the surfaces of the two companions are separated by what in astronomical terms is an extremely short distance. Moreover, some close binary stars are enveloped in a common mass of gas that revolves around the pair. It was tempting to assume, therefore, that these pairs had been formed by the splitting or fission of a single, rapidly rotating parent star. This hypothesis derived strength from a famous physical experiment attributed to the 19th-century Belgian physicist Joseph Plateau. In this experiment, a large drop of oil, the specific weight of which is approximately the same as that of a mixture of water and alcohol, is suspended in a vessel filled with the mixture. By stroking the drop with a thin rod, it is made to spin around its axis. In doing so it changes in shape and becomes more and more flattened. As the speed of rotation increases the drop assumes the shape of a ring and ultimately breaks up into a number of small detached droplets. Astronomers thought that a similar process might be operating in the stars. The reasoning was as follows. The stars contract as a result of their own gravitation. It is well known that when a rotating body contracts, its rotation speeds up, due to the law of conservation of angular momentum. Thus as a star contracts, it spins more and more rapidly around its axis. Finally the centrifugal force exceeds the force of gravitation, and when that happens, the star breaks into two or more parts

This theory was examined mathematically by the British astronomers Sir George Darwin and Sir James Jeans. Jeans, extending the work of Darwin, H. Poincaré and A. M. Liapunov, proved by mathematical methods that an incompressible substance, permitted to rotate around its axis at an increasing rate of speed, would first become flattened in the form of a spheroid. After a certain critical velocity of rotation was reached, the spheroid would gradually stretch into a cigar-shaped ellipsoid with three different axes. Then a furrow would

form in the middle of the body; the furrow would rapidly deepen, finally the mass would break into two parts. Jeans concluded that this process could account for the formation of double stars, and he defended the fission theory until his death in 1946.

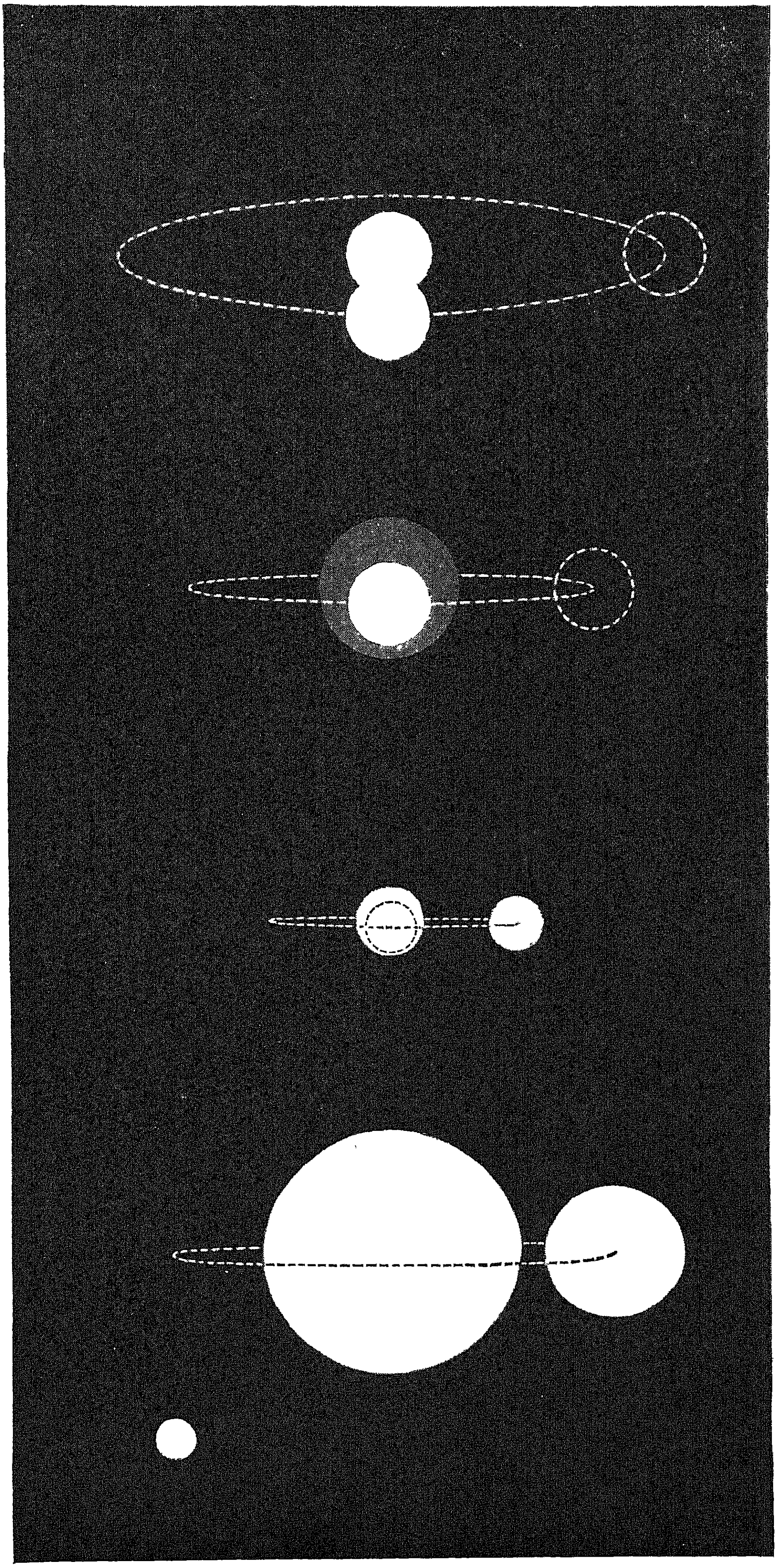
YET Jeans himself pointed out what is now regarded as the principal flaw in the theory. This is that the stars, as we observe them, have a great concentration of density at the center, in contrast with the theoretical mass of uniform density that Jeans treated. A real star may have a central density 20 times greater than the average density. A sphere of this type does not divide by the process of fission, but instead becomes lens-shaped and thins out to a sharp edge along its equator. If the rotation is gradually increased, matter will begin to stream off the sharp edge and form a flat ring around the star, resembling the ring of Saturn This process of ring formation has been observed in stars There are many rapidly rotating stars of high temperature which are not completely stable and lose gaseous atoms at the equator because the centrifugal acceleration more than balances the gravitational attraction.

The most famous object of this sort is Pleione, one of the seven bright stars in the cluster of the Pleiades. Pleione, a bluish star, has a ring whose plane very nearly coincides with our line of vision. Hence we observe the star's light through the gases of the ring, the latter produce absorption effects which we can record by means of a spectrograph. A study of these features reveals the dimensions of the ring and its composition, its density and its velocity of rotation around the star.

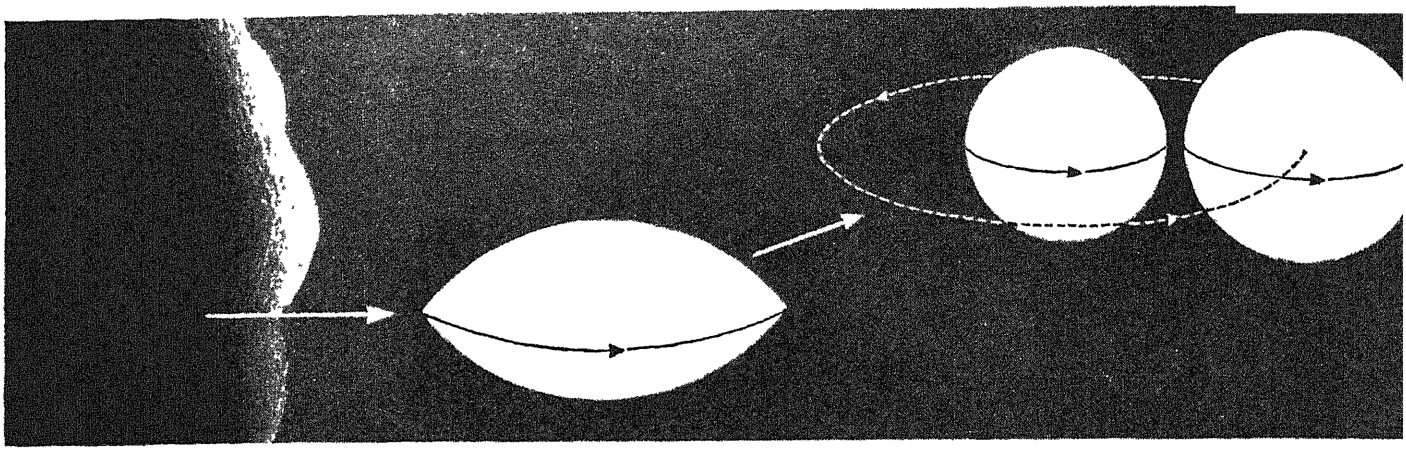
If we could observe Pleione with a magnification 1,000 times greater than the maximum that the turbulent atmosphere of our earth permits, we should be rewarded by a truly magnificent sight a bluish central star, greatly flattened at its poles because of its rapid axial rotation, surrounded by a tenuous ring, resembling the rings of Saturn, and shining in the distinctive hues of the radiation of hydrogen

There is no possibility that double stars can originate from such rings, because the rings are unstable. They disintegrate into space, and, so far as we know, they do not condense into planets or other bodies of considerable mass. So we must search for some other explanation of the origin of the binaries.

THE most promising theory appears to be that they are created by the explosion of single stars. The German physicist C. F. von Weizsäcker has suggested that the explosion of a supernova could easily produce a binary system. This theory would explain why there are



ECLIPSING BINARIES are double stars that revolve about each other in roughly the same plane as our line of sight. These four examples are, from top to bottom, Beta Aurigae, U Cephei, RT Persei and TX Cassiopeiae. Size of sun (*lower left*) is based on comparison with Beta Aurigae. Sizes of other binaries are based on assumption that mass of each pair is equal.



STELLAR EVOLUTION might begin with the formation of a massive star from a dust cloud. This star rotates so rapidly that its equator tapers to a sharp edge. It becomes a massive double star (example: U Coronae

so many double stars The German astrophysicist A. Unsold has shown that every star whose temperature is greater than that of the sun has a good chance of becoming a supernova once during its lifetime. On the average a supernova appears about once in 600 years in every galaxy. During historic times the Milky Way has probably had three: one observed by a Chinese astronomer in the year 1054; a second, bright enough to be seen in the day sky, noted by the Danish astronomer Tycho Brahe in 1572; and a third observed by the German astronomer Johann Kepler in 1604.

When we consider the formation of double stars, we must pay particular attention to the matter of angular momentum, or rotational energy, because a binary system, with two stars revolving around a common center of gravity, obviously has a great deal of such momentum. In all probability the two stars combined can possess no more rotational energy than was present in the original star, for it is unlikely that the explosion that produces the pair adds anything to the original system's angular momentum Hence it is probable that double stars of the type of Beta Persei can originate only from parent bodies with large rotational velocities. Now it is an extremely interesting fact that our galaxy contains vast numbers of rapidly rotating single stars: *i.e.*, potential parents of binaries. All of them are extremely hot. The cooler stars in the galaxy, of which the sun is one, never show large rotational velocities—except when they are double. The sun has a rotational speed of about two kilometers per second at its equator; at the opposite extreme there are hot stars whose rotation is of the order of 500 kilometers per second.

Immediately after a new binary star has been formed, the system must be in a greatly disturbed condition. And when we look for such systems, we find, indeed, that they are not especially rare. A good example is the famous eclipsing binary Beta Lyrae, which most astronomers believe to be one of the youngest double stars. We know that one star of Beta Lyrae's pair is an exceedingly luminous object whose radiation of light and heat surpasses that of the sun by a factor of 100,000 Since it probably derives its energy from the same nuclear process as the sun—the transformation of hydrogen into helium—we must conclude that Beta Lyrae will exhaust its available supply of hydrogen atoms 100,000 times more rapidly than the sun. It would take the sun approximately 100 billion years to convert its hydrogen into helium. Making allowance for the fact that Beta Lyrae's mass, and supply of hydrogen, is approximately 10 or 20 times that of the sun, at its faster rate of reaction it would use up its hydrogen in 10 million years. Hence Beta Lyrae, still producing energy at a tremendous rate, cannot be much older than 10 million years. For a star, this is a very short life.

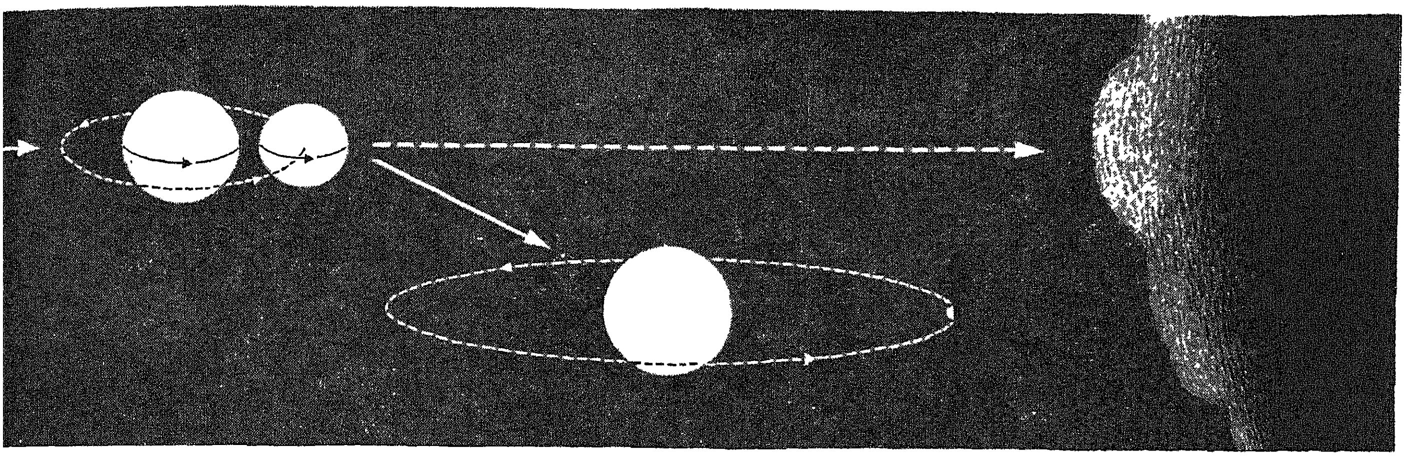
THE spectrum of Beta Lyrae shows many remarkable features which are not duplicated in any other known object of our galaxy It shows a set of strong absorption lines that come from an expanding ring of nebulous gas, possibly shaped like a pinwheel, which surrounds the entire system. In addition, there is a much more concentrated stream of gas which flows from the hot star toward its less massive, cool and invisible partner. This stream flows completely around the cooler component.

There are a number of other binary systems in our galaxy which we recognize as relatively young. In most cases the two components are surrounded by a common envelope of streaming gas that forms something like a nebulous ring around the whole system.

The ring of gas revolves rapidly in the same direction as the two stellar components, but the velocity of the stream is often much greater than that of the stars. As for the motions of the stars, in some systems the periods of axial rotation and orbital revolution coincide, that is, each star makes one complete turn on its axis in the same time that it swings a complete orbit, but in others they differ widely.

THE evolution of the nebulous envelopes around the binaries can be predicted from a theory of turbulence which has recently been applied to astronomy by von Weizsacker. We know from observation that such envelopes or rings do not rotate as solid bodies. At the outer edges, where the densities are extremely small, the individual atoms move as free mass points under the combined action of the gravitation of the two stars and the pressure of their light. At the inner edges, where the rings are in contact with the stars, their motions are constrained by the rotations of the stars themselves In consequence, there will be a gradient of velocity as we pass from the inside of the envelope toward its outer edge. In a stream with nonuniform motion two types of flow can exist. If the viscosity of the gas is large and if the differences in the velocities at different levels are not great, the flow will be smooth, but under other conditions the flow becomes turbulent and the medium breaks up into countless turbulent cells which move back and forth in random directions and dissipate energy through their collisions and interactions.

The mathematical theory of this process has been investigated by von Weizsacker. It turns out that the gaseous mass divides into two parts, an outer expanding ring of nebulosity which escapes to infinity and becomes a part of the interstellar medium, and an inner mass, much more condensed, which remains at the center of the system and retains only a small part of the original angular momentum of the rapidly rotating system. In this manner, a close double star gradually loses mass and angular momentum. We should expect that after an interval of the order of 100 or 1,000 million years, a system of the type of



Borealis), which evolves into a dwarf double star (example: W Ursae Majoris). These might coalesce into star like sun, with planets conserving angular momentum. They might also yield mass to interstellar dust.

Beta Lyrae or Beta Persei would lose about nine tenths of its original mass and angular momentum.

A change in the mass of a star inevitably means a change in its other physical properties. Its luminosity, its temperature and its radius decline A giant or supergiant binary may become a dwarf binary, of which W Ursae Majoris is an example Until recently we thought that dwarf binaries were rare, but Harlow Shapley of the Harvard College Observatory has now shown that they were little known only because they are faint and difficult to find. Per unit volume of space they are much more numerous than all other types of close binary systems Spectrographic observations made at the McDonald Observatory in Texas show that these dwarf binaries are surrounded by common envelopes whose properties closely resemble the envelopes of the giant binaries from which they have sprung. But their envelopes are denser than those of the giant binaries, and so the processes of dissipation must be speeded up. The dwarf binaries must disintegrate even faster than the giants.

WHAT happens then? Do the dwarfs ultimately disappear into space? No; the process of turbulence described by von Weizsacker suggests that ultimately the dwarfed pair will combine to form a single star. Here, however, a difficulty arises. The system of W Ursae Majoris, which resembles the sun in temperature and in the masses and luminosities of its two components, has a total angular momentum hundreds of times greater than that of the axial rotation of the sun. The law of conservation of angular momentum predicts that the single star descended from such a system would be one of very rapid rotation. Yet no such stars have ever been observed.

It is tempting to conclude from these facts that the end product of the evolution of a W Ursae Majoris binary is not merely a star but a star surrounded by a system of planets. Because of their great distances from the parent sun, the planets in a solar system carry in their orbital motions a large amount of angular momentum For example, in our solar system the angular momentum of the planets is 50 to 60 times greater than the angular momentum of the sun's axial rotation If, at some time in the distant past, the planets in our system had all been a part of the sun, its rotation then would have been of the order of 100 kilometers per second or more. This is not quite as large as the angular momenta of the W Ursae Majoris type of binary But it does suggest that possibly in the process of dissipation of the common envelope, planets are formed which retain part of the angular momentum of the W Ursae Majoris system, while the rest of the envelope escapes.

THUS a more or less comprehensive picture of stellar evolution begins to emerge. It starts with a great cloud of interstellar dust and gas that condenses to form a hot, rapidly rotating star. As the star contracts and spins faster, at some critical point it explodes catastrophically into a supernova. The exploding star forms a giant binary enveloped in a great ring of gas Gradually the system dissipates and shrinks to a dwarf binary. Finally the dwarf reaches a critical point at which its two components combine to create a single star with a company of planets.

If this picture is correct, it would imply that there is a continuous cycle from interstellar matter to massive stars, on through a stage of binary evolution, and back to interstellar matter. Every such cycle would leave as a residual product a single cool dwarf with its attendant planets. So perhaps our solar system is not a freak formation, as astronomers used to think, but represents a normal stage in the evolution of many, if not all, stars. The heavens may, indeed, be full of planetary systems like our own.

The proposed ideas involve a great deal of speculation, and they should not be taken as a final theory of evolution in the galaxy But the crucial result of observation—that single solar-type stars are never known to have a large angular momentum, while planetary systems and W Ursae Majoris binaries both have large supplies of it—suggests that there is a connection between binaries and solar systems which must be seriously considered.

The process we have described applies only to the close binaries, it fails to explain the numerous systems which are now so well separated that they are observable as visual double stars. It has been suggested, from time to time, that the wider pairs differ from the close, spectroscopic or eclipsing binaries in origin and subsequent evolution. This is, at best, a rather unsatisfactory explanation, because the properties of the binaries regarded as a function of the separation between the components change by gradual stages; they do not exhibit a tendency to form two distinct groups. Thus it may be that the evolution of the close binaries is not the one we have suggested, instead of combining they may gradually separate and become visual binaries. This difficulty must be recognized. It may help us to clarify many still obscure processes of evolution, or it may compel us to abandon the working hypothesis proposed in this article. But this is the way science progresses. No theory or hypothesis has ever been completely successful. To be useful it must lead future research into fruitful channels and it must contain a kernel of truth which becomes an integral part of all future theories. In the present case we venture to predict that this kernel consists in the peculiar absence of large rotations among the single solar-type stars.

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PHENOCOPIES

They are copies of the phenotype, the technical term for the visible characteristics of an organism. Their similarity to mutants launched a fascinating inquiry

by Richard B. Goldschmidt

IN 1864 an Austrian entomologist, Georg Dorfmeister, reported that he could change the typical pattern of a butterfly's wings simply by exposing the insect in the early pupa stage to extreme temperatures. His experiments, coming in the early days of Darwinism, attracted wide attention, for they could be interpreted—rather uncritically—as experimentally produced evolution. Soon it became a fashion among professional entomologists and the very large European group of amateur entomologists to subject pupae of butterflies to the most varied treatments and to record the effects upon coloration and pattern of the wings.

The experimenters discovered that changes of wing pattern could be produced by various kinds of shocks—short exposures to lethal heat or cold, asphyxiation with carbon dioxide, treatment with anesthetics, and so on. The most important finding was that effects could be obtained only when the treatment was applied within a short "critical" period soon after the pupa stage began.

There was much discussion about the meaning of these experiments for evolutionary theory—most of which is obsolete today in the light that genetics has since cast upon the mechanics of evolution. One result of the experiments that especially intrigued evolutionists was the discovery that butterflies of a particular locality, after being changed by experimental treatment, sometimes closely resembled other races of the same species found in other regions. For example, out of heat-treated pupae of the Central European swallowtail (*Papilio machaon*), butterflies occasionally hatched which resembled a variant race of this species whose natural habitat was Palestine. Pupae of the tortoise shell (*Vanessa urticae*) produced butterflies resembling the southern variety of this species (*ichnusa*) when they were treated with heat, and other forms resembling the northern variety (*polaris*) when they were treated with cold. In those pre-Mendelian days, these results were construed as proof that new forms in evolution were produced simply by the action of the environment. The advocates of this view were undisturbed by the fact that the same effects could be produced by heat, cold or chloroform. Experimenters rarely asked whether these effects were actually inherited; nor was it ascertained whether the geographical varieties in question were hereditary races or, if so, how they differed genetically from one another.

With the advent of modern genetics a different approach to these same results became necessary. Studies in genetics made clear that in considering a characteristic of an organism, such as the wing pattern, a sharp distinction had to be made between the genotype and the phenotype. The genotype, or hereditary pattern, is based on the genetic constitution of the organism, and is passed on from generation to generation. The phenotype, or visible pattern (from the Greek *phainein*, to show), is not necessarily based on inheritance; it may be merely an outward form produced by environmental factors. Thus the changed appearance of the butterflies hatched from treated pupae might be nothing but a temporary, nonhereditary modification that would not be passed on to the butterflies' descendants. And the occasional resemblance of the modified individuals to other forms that were assumed to be genetically distinct races might be a chance coincidence. Even if it could be demonstrated that the experimentally induced changes could be inherited—as was in fact claimed by two investigators, but never proved by proper tests—it might merely be that the same treatment that produced the phenotype might sometimes also produce a true genetic change, a mutation.

Unfortunately the investigation was dropped at this interesting point and suspended for several decades. Most geneticists and evolutionists forgot about these once-famous experiments.

BEGINNING in 1927, I embarked on experiments of a similar type, this time backed by the accumulated knowledge of more than 25 years of genetics. Instead of butterflies, which are difficult to breed over many generations and are not well explored genetically, I chose a more convenient organism, the fruit fly, *Drosophila*, the most fully studied of all organisms in regard to heredity. My expectation that shock treatments of fruit flies would produce effects comparable with those in butterflies was more than fulfilled.

We found that by applying heat shocks to purebred, or homozygous, young Drosophila pupae of perfectly normal ancestry we could produce adults which were changed in one or more of their visible characteristics so as to be identical with well-known mutants of this fly. Hundreds of such hereditary variants are known in Drosophila, and every geneticist can distinguish and label these mutants of the eyes, wings, body, legs, and so on, and follow their simple heredity according to the Mendelian law. Each of the visible types of flies obtained in the temperature experiments was absolutely identical with one or another of the known mutants. Since they were copies of the visible form of such mutants, they were naturally christened phenocopies.

No phenocopy was ever transmitted to the altered fly's descendants; the offspring of these pseudomutants were and always remained normal. In my own experiments and those of other investigators, it developed that almost any known type of mutant, even some of the rarest and most extreme, could be duplicated as a nonhereditary phenocopy. Indeed, the only class of mutants we have been unable to copy thus far is the one associated with simple chemical changes, such as eye or body color. This exception may have a definite meaning but may also be a chance result. At any rate, it can be stated with confidence that, with this single possible exception, the phenotype of any mutant of the fruit fly can be produced experimentally as a phenocopy by means of a change in the organism that does not affect the germ plasm.

BIOLOGY often is a process of rediscovery; when we discover a new principle we begin to look at familiar phenomena with new eyes. Having been

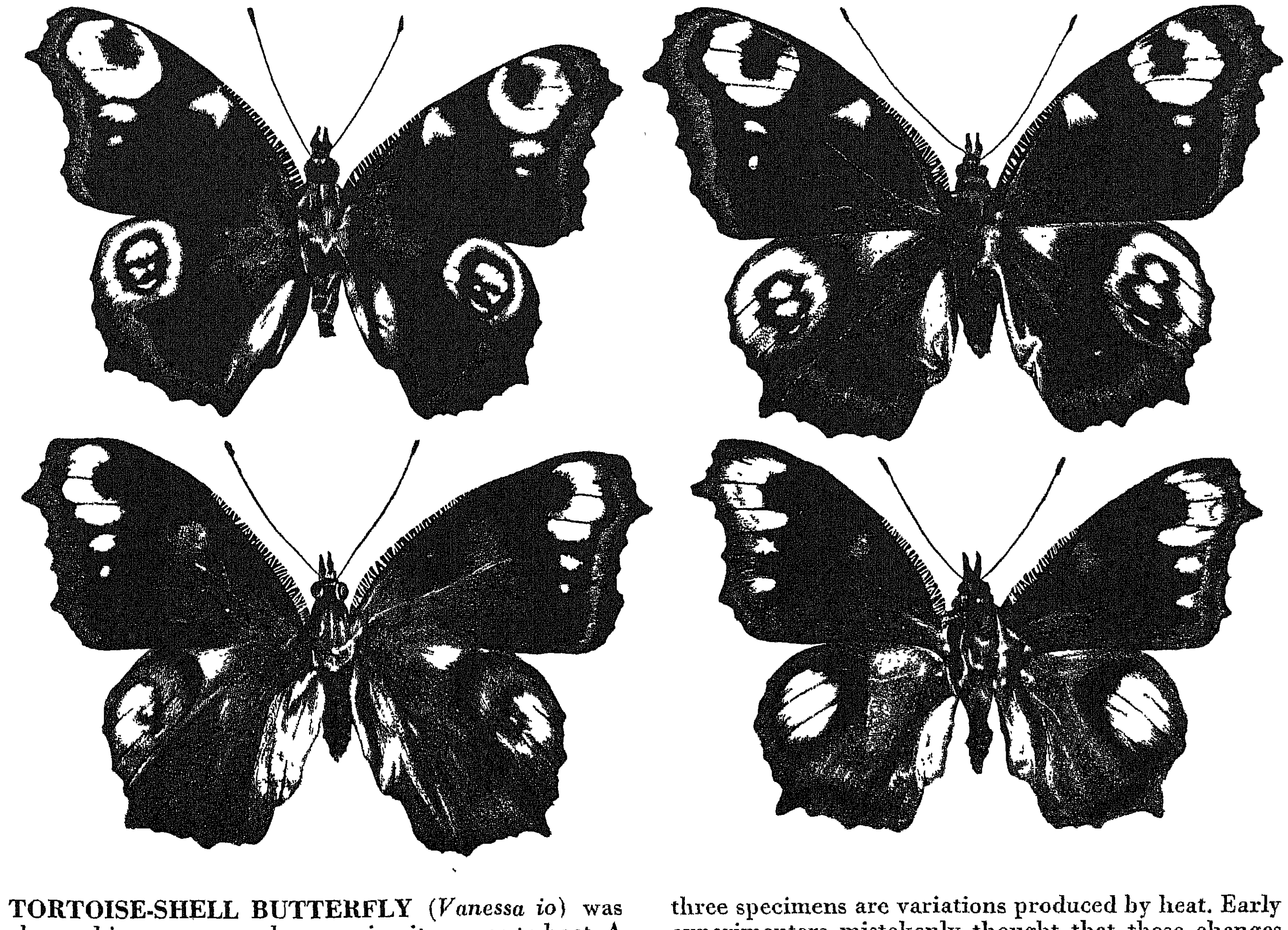
alerted to the existence of phenocopies, one would expect to find them not only in insects but in other species of animals, and not only in experimentally changed animals but in nature. And so indeed it turns out, investigators have now found phenocopies in many organisms, among them moths, birds, mammals, bacteria. Even in man there is a peculiarity that can be interpreted as a phenocopy: this is the occasional occurrence of certain abnormalities of the eyes and the central nervous system which resemble known hereditary conditions but are not genetic—they result from infections of the mother, known as toxoblasmosis, during pregnancy

Our original phenocopies of Drosophila were produced by heat shocks. It has been found since then that a large variety of other shocks can produce the same result. The only thing common to all these treatments is that they are outside the range of environmental actions to which the organism is normally exposed and they act so heavily upon the organism that only a few individuals survive the shock. The maximum number of phenocopies is produced when the treatment is sublethal, meaning that it kills a large proportion of the exposed individuals but leaves a number of survivors This fact is clearly of great importance as a clue to what is going on in the organism when a phenocopy is produced.

The most potent agents for production of phenocopies are heat shocks and irradiation with X-rays. Also effective are cold shocks, certain other radiations, especially bombardment with neutrons, and certain chemicals, provided in the atmosphere or in the food.

To produce phenocopies these shocks must, however, be properly applied, which means, as already indicated, that they must be administered during a critical period in the development of the organism It is a well-established fact of embryology that a developing embryo lays down the successive steps of its organization in a way which can be described as successive determination This means that the first steps of the formation of an organ do not establish this organ irrevocably. It is still possible to change the course of developmental events by experimental interference. But at a definite time and stage in the development of each organ of the embryo, a moment comes when the future of the rudiment, or bud, of the organ is determined practically irrevocably. For example, when the rudiment of a future arm in a vertebrate embryo begins to form, a shock can force the rudiment to develop into a leg. But once the rudiment has reached a certain age and stage, no experimental procedure can prevent it from forming an arm. There is a definite time of final determination for the organ, and also for its parts, so that its development as a whole can be conceived as the occurrence of an orderly series of steps of more and more detailed determination.

A COMPARABLE, and actually parallel, phenomenon exists in the field of developmental genetics Suppose there is a mutant of Drosophila that reduces to 100 the number of eye facets in the fly, normally about 1,000. If such a hereditary line is reared at different temperatures, the facet number may be changed to another average number according to the temperature used. By applying the changed temperature only during exactly determined time intervals in development, one can show that the effect occurs only when the exposure takes place at a definite limited period during development. It is obvious that these well-established groups of facts from embryology and developmental genetics bear a relation to the critical



TORTOISE-SHELL BUTTERFLY (*Vanessa io*) **was changed in appearance by exposing its pupae to heat. A normal specimen is shown at the upper left. The other three specimens are variations produced by heat. Early experimenters mistakenly thought that these changes could be transmitted from generation to generation.**

time at which phenocopies are produced. In all three cases we may speak of a critical period in which something happens or can happen.

Ever since phenocopies became known, much effort has been directed to the determination of these periods. It was found that a critical period could be established for almost every experimental phenocopy. Generally this period precedes the visible differentiation of the particular structure concerned, which is to be expected, because experimental embryologists have shown that the nature of an organ usually is determined before its differentiation becomes visible All our experiments indicate that a shock treatment within certain time limits during this sensitive period not only affects the immediate development of the organ but forces later developmental processes into such channels that the end product, the phenotype, is indistinguishable from that of a mutant. Normal environmental conditions and the usual, or "wild type," genetic constitution of an organism will send the developing organ down one road, on the other hand, either an appropriate shock treatment or a different hereditary factor will send it down a new path which ends in a common result although the causes are different

CLEARLY the next step in the analysis of this phenomenon was to find a method by which specific phenocopies could be produced at will. For example, was it possible to select a specific treatment of larvae or pupae which would make all the flies hatched from them imitate the type of a particular wing mutant? In my first studies I had found that a certain wing type in Drosophila could be obtained only when the larvae were exposed to precisely 35 degrees Centigrade; a deviation of one or two degrees from this temperature failed to produce the same result. But on the whole these early experiments were not satisfactory in producing specific phenocopies. Subsequent experiments with chemical treatments, however, have been more successful. A Russian geneticist, J. A. Rappoport, has laid claim to a considerable array of positive results He obtained one type of phenocopy in fruit flies with antimony compounds, another with arsenic, a third with silver lactate, and so on. In each case 100 per cent of the treated individuals displayed the same specific and distinctive phenocopy.

Within limits some of these results have been confirmed: for example, Eileen Sutton-Gersh of Johns Hopkins University, as well as Rappoport, treated Drosophila with boric acid and produced flies with typical melanotic (*i e.*, black-pigmented) tumors. These were precisely like tumors that are known to exist as hereditary strains. However, we produced the same tumors with another chemical and with heat shocks as well—so boric acid apparently is not a specific agent for this phenocopy. Another investigator found that ether or phenol, applied to Drosophila at very early developmental stages, produced flies with four wings instead of two.

Perhaps the most interesting phenocopy of all, from the standpoint of suggesting a chemical explanation of what happens when a phenocopy is produced, was created by the geneticist Walter Landauer of the University of Connecticut. He worked with chickens A well-known mutant in fowl is the rumpless condition, all or nearly all the tail structures are absent. Landauer succeeded in producing this remarkable aberration of the skeleton and the entire posterior region of the chicken's body as a phenocopy. He did so by injecting young eggs with insulin Now insulin, as every biologist knows, influences carbohydrate metabolism. Thus Landauer's experiment suggests that it may be possible to link a striking change in appearance, such as is produced in a phenocopy, with specific details of metabolism. By the same token, it may even be possible to show that the genes exert their effect in shaping an individual by acting on metabolic processes.

THIS leads to the great and decisive question looming behind all these facts: What is the relation of phenocopy to mutation? What is the reason for the similarity between phenotypic action and the action of a mutated gene? Ignoring for the moment the possible specific effects of particular chemicals, we are confronted by the primary fact that such radically different agents as heat, cold, anesthetics and radiation produce the same effects, provided they act at a definite critical time of development of the individual. This must mean that all these various kinds of shocks act upon some generalized feature of development in the organism, some mechanism that can be shifted out of its normal course by any kind of damaging action. If we liken this mechanism to a railroad, the possible shifts in direction are limited to a few fixed tracks.

What do all the shocks, or switchmen, if you like, have in common? They are all of a type that we would expect to hinder or to slow up life processes. We know that in the living body an increase or decrease of temperature, within normal environmental limits, increases or decreases the speed of reactions. There is a well-known mathematical law that applies here: each rise or drop of 10 degrees Centigrade doubles or halves the rate of reaction But this holds only up to the limits of normal tolerance, beyond those limits heat and cold alike throttle and finally halt the process in question. Large doses of radiation and of anesthetics likewise are known to act in this detrimental way. Therefore it appears safe to assume that the phenocopic agent slows up or stops some key reaction or series of reactions going on during the critical period for a particular structure In this exactly timed series of events, one of the most crucial is the proper sorting out of the substances that an organ needs for carrying out its specific processes of organization. We might say that at the moment when this sorting-out process has been accomplished in a certain part of the developing organism, say, to put it crudely, when an arm substance or leg substance has been deposited, the point of determination of the organ has been reached, this is the moment when the future fate of the part is irrevocably decided. But as all developmental features must be intimately interwoven in order to produce a normal whole, a perfect timing of all these determining processes in their specific hierarchical order is needed to yield the standard end product—the organism with all its typical features down to the last hair or speck of color. We might roughly compare this building of an organism to the operation of an assembly line. The line must move with a definite speed. At a definite time a particular piece must be attached at the proper site If one piece is left out at a given time, all subsequent operations are impossible. Let us not overwork the comparison, but its use may help us to realize how a change in the speed of developmental features at a critical time will affect all later processes and therefore will produce a quite different end product, if indeed it does not utterly destroy the whole fabric of development. (Remember that phenocopies appear when the action of the agent is almost fatal.)

The phenocopy, then, is the result of throwing out of gear the precisely interlocked and precisely timed processes of embryonic differentiation. It seems obvious that there cannot be many ways in which so much harm can be done without destruction of the entire integration of the processes. The few avenues available for such changed but still feasible development are probably of a plus-minus, slower-faster type

It is easy to understand that by such induced shifts an abnormality, even a monstrosity, can be produced. But why the likeness to a mutant, which is a change of structure and therefore of development produced by a change in the hereditary material? If a full answer to this problem could be given we might behold the answer to the basic riddle of genetics: What is a mutation?

A MUTATION can only lead to viable mutant forms of a new and hereditary type if the effects of the genetic

change in the chromosome do not interfere too much with the orderly course of the interwoven processes of development. This means, then, that a viable mutant is limited by the same features as a viable phenocopy. Just as a phenocopic agent can act only upon the restricted tracks along which developmental processes are taking place, and only in a limited plus-minus way, so the mutant gene cannot produce a viable organism if it does not act upon the same tracks in the same way. A mutant gene therefore must differ from the original gene in such a way as to affect one of those limited possibilities of a plus-minus change in the most intimate processes of development. What this change is in chemical or physical terms is still a mystery.

Mutant and phenocopy, then, look alike because changed genetic action as well as action by a phenocopic agent is limited to definite tracks. There can be no doubt that in the last analysis the primary change produced both by phenocopic agent and mutated hereditary material must be of a chemical nature. But there is no reason to assume that it is identical in both cases. If the tracks on which a developmental change can run are prescribed and limited, quite different primary causes may lead to an identical effect. A railroad car will roll along its track whether pushed by a gang of men, a locomotive, a small explosive charge, a vagrant breeze or whatever. If the push is too great, it will, of course, be derailed

The present trend among geneticists interested in evolution is toward the analysis of the statistical basis of evolution, the distribution of types in a population and the conditions for selection. It is frequently forgotten that hereditary changes which may lead to evolutionary changes are limited by the possibilities for changing the developmental pattern of an organism without impairing its vitality. The study of phenocopies and their relation to mutation shows clearly that every departure from the norm produced by mutation can also be accomplished as a phenocopy. I do not hesitate to draw from this the inverse conclusion that any departures from the norm produced by the action of phenocopic agents should also be obtainable as mutants, even in those cases in which no presently known mutants supply the phenotype resembling the phenocopy. This conclusion suggests that future work on phenocopies will be most illuminating in what it has to tell us about evolution.

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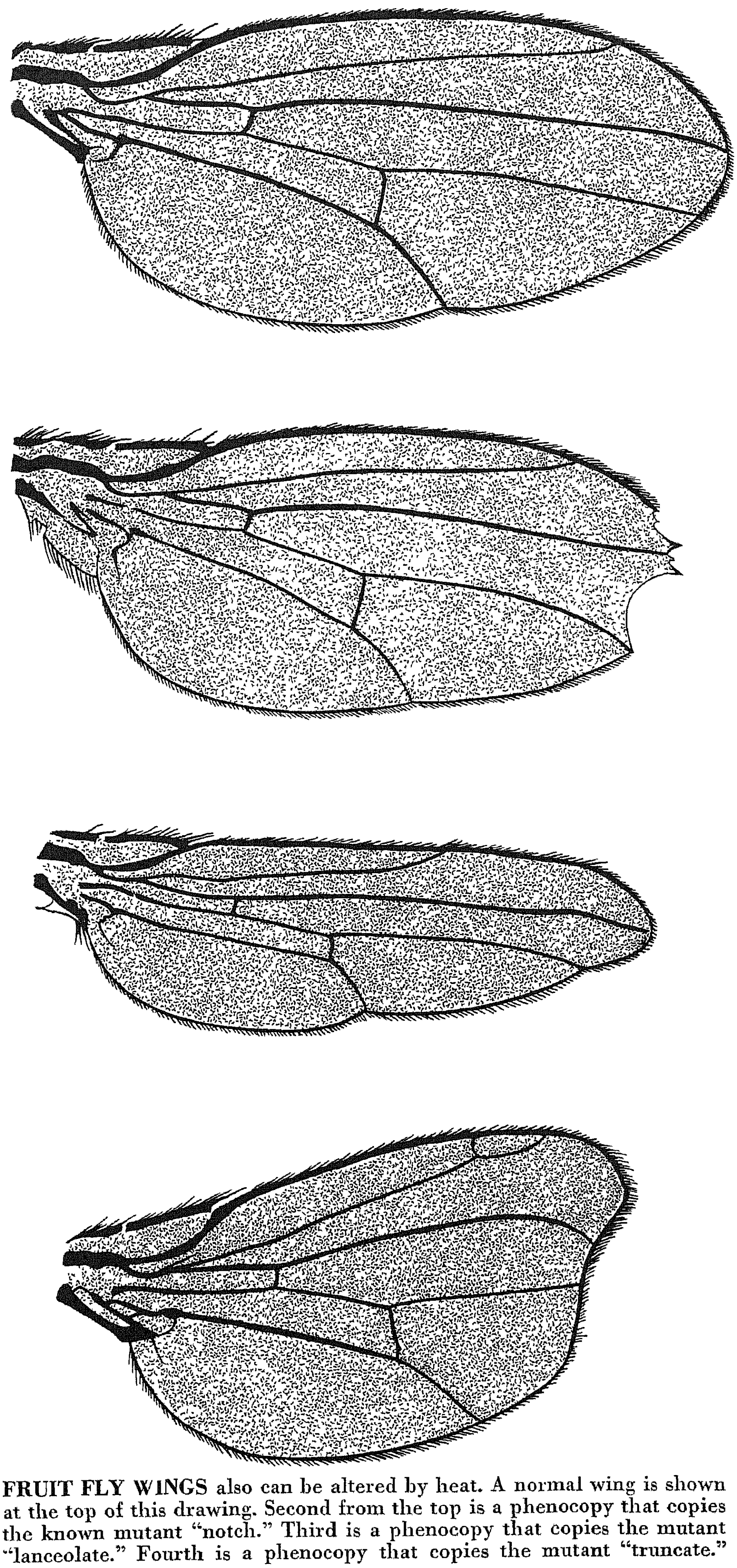


FRUIT FLY WINGS also can be altered by heat. A normal wing is shown at the top of this drawing. Second from the top is a phenocopy that copies the known mutant "notch." Third is a phenocopy that copies the mutant "lanceolate." Fourth is a phenocopy that copies the mutant "truncate."

Freud Now

At 82 the founder of psychoanalysis wrote the final statement of his system. A noted psychoanalyst gives his views on the present condition of Freud's legacy

by Fredric Wertham

ALMOST 30 years ago an historic debate on the value of psychoanalysis took place in Vienna before the Society for Applied Psychopathology and Psychology. The discussion was animated and the critics numerous. The occasion is worth recalling now because it was a turning point in psychiatry and produced a clear summary of Sigmund Freud's fundamental contributions to psychology before they were befogged by his numerous later interpreters. At the end of the meeting a psychologist, now a professor of psychology at a Catholic university in the U. S., enumerated the gains of permanent value contributed by psychoanalysis:

1. A better appreciation of sexuality, especially of sexuality in childhood.
2. The recognition of personality as a unit representing the individual's entire biological background and psychic experience.
3. The recognition of the existence of different psychic layers—consciousness, the preconscious and the unconscious.
4. The recognition of the mental mechanisms of repression, condensation and displacement.
5. The significance of symbolism in dreams—with reservations.
6. The recognition of sublimation—also with reservations.

Thus with a great deal of resistance, both unconscious and conscious, on the part of psychologists, a long step forward in psychiatry was reluctantly and half-heartedly—but nonetheless definitely—acknowledged. Even if Freud had achieved only the minimum set of accomplishments conceded at this critical meeting, these were sufficient to revolutionize the science of psychiatry. For if personality was not recognized as a unit, if sexuality was not sufficiently appreciated, if the existence of different psychic layers was not recognized, how inadequate must the pre-Freud understanding of mental processes have been!

To create and establish the new science—which we now call psychodynamics, or "deep psychology"—Freud had to perform a labor of Hercules He did this first alone, then with a few coworkers, and finally as the head of an international scientific school. He became probably the most famous psychiatrist of all time, and toward the end of his life he was treated like Socrates. But he was not killed; he was exiled. In 1938, at the age of 82, he sat down undaunted and wrote a summing-up of psychoanalysis. This little book of only 127 pages has now been published in English with the title *An Outline of Psychoanalysis*

It would be presumptuous to praise this book in the ordinary terms of gratified appraisal or formal respect. No other psychiatrist or psychologist of our time could sit down at the end of his life and look back on such a long chain of original work as could Freud.

Freud's final work is a survey of psychoanalysis in compressed form. It is a crystallization of psychoanalytic thought. But it would be a pity if it were taken merely as a contribution to the current trend to satisfy intellectual curiosity in digest or synopsis form. This work is not a synopsis. It is a full statement. It can be read at different levels. You can gain from it a view of the field of psychoanalysis; but you can also read it at a deeper level where it is at the same time a dissection and a synthesis of what Freud considered the most important tenets of psychoanalysis. It is therefore an indispensable book for any scientist who wants to be abreast of current psychological thought. It is the type of book that is so good that once you have taken it up, you *do* lay it down again, in order to think for yourself.

It is evident that Freud took great pains in writing this book. He was anxious to convey exactly and clearly what he thought and what he wanted to stress, and he evidently took equal pains to omit what he wanted to leave out. We are obliged to take these details seriously. Freud himself was not completely satisfied and did not quite finish the book. But he was so near its completion that this fragmentary form makes one think of the esthetic completeness that a torso can have in sculpture.

IT is significant that Freud wrote *An Outline of Psychoanalysis* more from the point of view of the scientist than that of the therapist. In this summary work he took pains to clarify and make more precise his definitions of the basic concepts. the *id*, the *ego* and the *super-ego* The book abounds in excellent formulations of the nature and functions of these elements For instance, he describes the region of the id. "It contains everything that is inherited, that is present at birth, that is fixed in the constitution—above all, therefore, the instincts, which originate in the somatic organization and which find their mental expressions in the id in forms unknown to us." He also describes clearly the problem of psychoanalysis: "The analytical physician and the weakened ego of the patient, basing themselves upon the real external world, are to combine against the enemies, the instinctual demands of the id, and the moral demands of the super-ego."

His brief chapter on the technique of psychoanalysis is a model of didactic clarity, and at the same time shows his sincerity and self-criticism. In view of the exaggerations of some of his conservative American followers, who have become more Freudian than Freud himself, it is a relief to read his calm, mature conclusion that "it makes no difference whether a child has really sucked at the breast or been brought up on the bottle." He points out gaps in one of the most vulnerable areas of psychoanalytic thought—the great importance assigned to the pleasure principle as a motive for behavior—and opens vistas for further work.

The clearest and most impressive chapters are those on mental qualities

and on dream interpretation, which deal with the most valid part of the whole psychoanalytic structure. The triad of mental qualities—consciousness, the preconscious and the unconscious—which has become an indispensable part of thinking in psychology, Freud regards as "not a theory at all but a first attempt at a stock-taking of the facts of our *observation.*" *He summarizes: "Processes* in the unconscious or in the id obey different laws from those in the preconscious ego."

In the chapter on dream interpretation he goes to the heart of his dream theory in this terse statement: ". . . dreams are invariably the product of a conflict . . . Something that is a satisfaction for the unconscious id may for that reason be a cause of anxiety for the ego." He repeats his felicitous, never-refuted statement: "The dream is the guardian of sleep."

WHAT are the points that Freud particularly stresses in this, his final statement? He makes the foundation stone of deep psychology the conflict between the libido and the death instinct: "This interaction of the two basic instincts with and against each other gives rise to the whole variegation of life." He speaks emphatically, but not with his usual lucidity, of aggressive impulses, aggression and aggressiveness. (Nowhere does he define these terms very clearly.) He sees fundamental differences in the psychological and sexual development of men and women, he places women decidedly in an inferior role. He assigns a central position to the castration complex. All through his presentation, he lays prime emphasis on the quantitative factors in the organization of normal and abnormal mental life.

Such, in brief summary form, are some *of Freud's final conclusions.* We are of course interested in the larger question: Where has psychoanalysis arrived after half a century? The *Outline* gives a cross section of psychoanalysis at the time of its writing. There is practically no reference to its historical development. If we wish to evaluate on the basis of this book the status of psychoanalytic thought today, we must of necessity supply a historical background to Freud's presentation. Here, as so often, the history of a science is that science itself.

One should make clear that, aside from the host of new clinical facts about patients that he observed, Freud brought about three fundamental changes in the approach to the study of personality and mental pathology. The first was to speak of psychological processes at all, and to think of them with the logic of natural science. This became possible only when Freud introduced the realistic concept of the unconscious and practical methods for its investigation. The second was his introduction of a new dimension into psychopathology: childhood. Before Freud, psychiatry was practiced as if every patient was Adam—who never was a child. The third was his inauguration of the genetic understanding of the sexual instinct. His real discovery here was not so much that children have a sex life, but that the sexual instinct has a childhood. Recognition of the existence of these pre-stages of adult genital sexuality (*regardless of whether Freud was* entirely correct in his analysis of the actual details) has become one of the cornerstones of the scientific study of human sexual life and its disorders.

These new insights based on new observations are high points in the long and laborious historical development of Freud's thought. To gain a critical view of psychoanalysis today, we have to go a little more deeply into this history. I have found it useful to distinguish schematically certain stages in the development of psychoanalysis.

In the first stage, in the 1890s, Freud discovered the pathogenic significance of the content of an individual's mental life, as opposed to the previous emphasis on the form of mental states. Freud's early co-worker, Joseph Breuer, for instance, thought that the only experiences or images that could lead to mental illness were those which occurred in special formal mental states, such as the so-called "hypnoid" state. Freud, on the other hand, saw the neurosis as a defense against circumscribed contents of

SIGMUND FREUD wrote his last book as an exile in England. Here he is depicted at his famous desk in Vienna. Atop the desk were statues of primitive cultures whose customs he invoked to support his system.

A GLOSSARY OF FREUDIAN TERMS

PRECONSCIOUS	A psychic layer, or level of mental activity, of which we are not consciously aware but which is distinguished from the unconscious by the fact that it has the same formal structure as conscious thought.
UNCONSCIOUS	A psychic layer which is characterized not only by lack of conscious awareness but by special laws: *e.g.*, the presence of symbolic expressions and images; the free flow of libido; the absence of distinctions between the past and present, the subject and the object, fantasy and reality.
LIBIDO	A concept denoting sexual energy in the broadest sense.
ID	The mental representation of primary instincts.
EGO	The self, that part of the id which has become organized by adaptation through influences of the environment.
SUPER-EGO	The conscience, the psychic focus of restraining forces in an individual which are derived from his parents and society.
REPRESSION	A mental mechanism whereby thoughts or wishes that would be unpleasant if conscious are relegated to a layer below consciousness.
DISPLACEMENT	The mechanism whereby the emotion attached to one idea is shifted to a more innocuous one.
SUBLIMATION	The deflection of repressed sexual strivings toward other aims.
CONDENSATION	The representation of two or several ideas by one word or image.
TRANSFERENCE	The shifting to a new person of a positive or negative attitude based on the pattern of a repressed relationship with another person in one's past life.
NARCISSISM	The turning or returning of the libido toward one's own ego.
REGRESSION	Retreat to an emotional pattern of the past.
REPETITION	The tendency of certain neurotic phenomena to repeat themselves; independent of the pleasure principle.
RESISTANCE	The emotional counter-force which prevents repressed thoughts, feelings or memories from reaching consciousness.

the mind which were incompatible with the dominant tendencies of the patient's mentality.

This emphasis on content was a thorn in the flesh of the contemporary academic psychologists. In 1927 the famous Austrian experimental psychologist Karl Buehler was asked to deliver a lecture at Johns Hopkins University. He was wholeheartedly opposed to psychoanalysis, but knowing its attraction he chose it as a subject for his lecture—just as a preacher can speak about the devil and his works as long as he is against them. Buehler was particularly against Freud's scientific attention to circumscribed mental experiences, that is to say, the contents of mental life as against the formal aspects which the experimental psychologists had studied so patiently. In German the word for content, *Inhalt*, is sometimes used by philosophers interchangeably with the word *Stoff* (matter). So Buehler called his lecture "Freud the Stuff Thinker"—and kept on talking about "stuff thinking" for a whole hour. His huge audience, which had expected him to talk about sex (against it, of course) was both disappointed and bewildered. Nobody had any idea what he was talking about.

In this first stage Freud overrated, as he himself pointed out later, the role of sexual traumas in childhood, which he considered the chief factor in causing neuroses.

IN the second stage, centering in the publication of his *Three Contributions to the Sexual Theory* in 1905, Freud evolved the conception of "circumscribed perversion tendencies." He studied and described their relation to the psychosexual constitution and to character in general. At this stage a German pupil of Freud, Karl Abraham, made a great step forward in our understanding of schizophrenia, then called dementia praecox. Abraham pointed out in 1908 that in this disease the capacity for both transference and sublimation is greatly reduced.

In the third stage, the period during which Freud published his important work *Introduction to Narcissism* (1914), the interest of psychoanalytic theory shifted from repression and the repressed to the repressing principle, that is to say the ego tendencies. Freud now formulated the important conceptions of narcissistic regression and classified a whole group of psychoses as narcissistic conditions. This stage might be called the stage of ego psychology.

In the fourth stage, ushered in by *Beyond the Pleasure Principle* (1920), a decisive turn in theory took place. Starting from studies of traumatic war neuroses, Freud introduced a new principle which under certain conditions replaces the pleasure principle, namely, the tendency to compulsive repetition of

acts or experiences. From this repetition tendency Freud logically derived the idea of a tendency toward death He now saw the two opposing forces in mental life not as libido and ego instincts but as life instincts and death instincts

The date of the beginning of this gloomy theory (1920) is not accidental. But the war and the clinical observation of war neuroses of which Freud spoke were not the whole explanation of his new theory, nor even its most important part. A brilliant psychoanalyst, Leo Kaplan, wrote in 1916 "The dependence of thought on circumstances of the time usually remains unconscious to the thinker himself" I am convinced that first the hope and then the breakdown of the democratic transformation in Central Europe influenced Freud's thinking Analytically speaking, there is evidence of this in his writings

I regard as belonging to a fifth stage the period of *The Ego and The Id* (1923). This was the work in which Freud first suggested the existence of an unconscious part of the ego, which he called the super-ego. He had observed that during the psychoanalysis of patients the analyst often encountered resistance from the ego, rather than from the unconscious. The older idea that such resistance always arose from a conflict between the ego and the repressed unconscious no longer sufficed. To explain the unconscious resistance belonging to the ego, he formulated the concept of the ego ideal or super-ego, which is derived from the Oedipus complex, *i.e.*, it originates primarily from identification with the parents.

It is interesting that in the same year in which Freud studied so carefully the relationship of the repressing agencies to the unconscious, he published a paper in which he emphasized more definitely and clearly than ever before that the Oedipus complex was one of the main pillars of psychoanalysis. The Oedipus complex is of course a crucial issue. It is a wedge that opens the door of psychoanalysis to the social factors in psychopathology. But Freud, having opened this door, chose to pursue a different path, toward a strictly biological interpretation of mental illness. It is an odd and superficially unexplainable fact that Freud never gave much attention to the social pressures that play so large a part in neuroses, the word social does not even appear in the index to his *Outline* His orientation when he deals with the larger aspects of psychoanalysis is biological. The social is, one is tempted to say, repressed.

Looking at *An Outline of Psychoanalysis* in this historical way makes it easier to take a broad, critical view. The essential paradox is that psychoanalysis, which made psychology and psychiatry more human and introduced the facts of life into the social sciences; has in these last writings of Freud become so abstract, so inhuman. In a revised version of the book Freud wrote "Psychoanalysis has little chance of becoming popular." At the very moment of writing this article, I have received a letter from a magazine asking me to write an article to explain the enormous popularity of psychoanalysis. The mushroom growth of psychoanalysis in the U. S is itself an important social fact.

While Freud was inclined to pay little attention to the philosophers, there is definitely a philosophical background to

DAUGHTER ANNA accompanied Freud in his days of exile. Today she is a child psychologist in England.

his views. It would not be difficult to show that he progressed from a materialist point of view, anchored in natural science, to a mechanistic idealism which —as it so often does—leaves great loopholes for reactionary mysticism There are passages in his book which might have been written by the German physicist and philosopher Ernst Mach, whose philosophical point of view led him to deny the possibility of the real objective existence of the atom. Freud writes, for example: "Reality will always remain 'unknowable.'" How far this metaphysical idealism of Freud's goes is shown by his speculation that space itself may be nothing but the projection of the extension of the intrapsychic apparatus which he is able to describe so well in his *Outline*.

THIS philosophical bias breaks through in his conception of the death instinct. It is wrong to think that this death-instinct theory is just a minor excrescence which can be disregarded without affecting the rest of his ideas. On the contrary, it is the logical outcome of a development that started about 1920, and it affects Freud's to my mind dubious theories that aggression and sadism are a "displaced death instinct."

With the wide acceptance of the death instinct, with all its clinical and social implications, the "deep psychology" of psychoanalysis goes off the deep end. There is an intrinsic similarity here to the position of Martin Heidegger, the existentialist who became one of the most influential Nazi philosophers. Reading Freud's *Outline,* one is reminded of some of Heidegger's formulations "Man . . is a finite creature, placed between birth and death, full of anxiety, and guilty, who is called by death to his very own ability to be. His being is a being unto death." I am not comparing a sophist like Heidegger with one of the greatest scientists of our time, but I do say that their philosophical ideas stem from the same socio-historical conditions of our epoch, and that the influence of these ideas on science is intrinsically regressive.

There are many details with which one could fill in this picture of the latest development of psychoanalysis as the introversion of a science. To be sure, Freud cannot be held responsible for what his epigones do and write. In our time it is difficult really to experience one's experiences, to comprehend the cold-blooded violence of contemporary events, about which we get only statistical news. The old-style conservative psychoanalysis has not helped people here. It has excluded the social scene in favor of the individual, action in favor of introspection, and history and economics in favor of biology. That of course has had its effect on the validity of psychoanalytic theory and the results of its therapeutic practice. The ingrown school of orthodox psychoanalysis has developed analysts who have raised to the nth degree the disdain for diagnosis of living people and turned instead to the development of more and more refined psychological mechanisms. I have seen the results of this type of thinking and practice not infrequently over the years. It sometimes reduces psychoanalysis to a practice that knows only one diagnosis, one etiology and one cure. Freud's *Outline* does not contain a word of warning that unless there is a continuous clinical checking of the psychoanalytic schemata in the individual case, there is the danger of a prolonged psychoanalysis turning into the disease which it started out to cure. Nor does the *Outline* counteract the present-day flirting of some analysts with certain currently fashionable phenomena that might be called extra-common-sensory perception.

One important lesson taught by the latter-day development of psychoanalysis is the intricate relationship between theory and practice. In his last phase Freud—and even more his followers—became entangled in the idea that human beings possess an innate aggressiveness,

linked to destructiveness, which must find release if mental health is to be preserved. Overdoing the originally correct principle of quantity in mental life to the exclusion of the clinical principle of quality, Freud in the *Outline* arrived at schematic statements such as this "A surplus of sexual aggressiveness can change a lover into a sexual murderer, while a sharp diminution in the aggressive factor will lead to shyness or impotence."

This reasoning may—and in Freud's followers often does—lead to an over-mechanical evaluation of early experience and tendencies, and to a disregard of the all-important defensive aspects of aggressive behavior. What does that lead to in practice? Psychoanalysts divert attention from the important task of arranging the social conditions of mature people so that waste, destruction and exploitation may be reduced and abolished. They have made many people believe that if you analyze aggression in the kindergarten you don't have to fight it in the grown-up world. Where the pre-Freudian psychiatrist treated an Adam who had no childhood, the post-Freudian psychiatrists are prone to put so much emphasis on Adam's childhood that they leave out the fact that he became a man with adult troubles, work and experiences.

Their explanation of cruelty as sadism, and of sadism as the death instinct, in my opinion has disqualified the more orthodox devotees of Freud from facing the anxiety-producing reality of violence in our time. How much more scientific psychoanalysis was in its earlier period than in the present can be seen in its attitude toward the social influences brought to bear on the child himself with regard to violence. In the middle 1920s Wilhelm Stekel wrote: "Intelligent parents should see that their children do not become mere 'bookworms' who devour one book after another and so lose their sense of reality Many a boy and many a girl have been made unhappy by bad books. . . . Only the best is good enough for the growing child. . . . Fairy tales, at least in the form that Grimm has given them, are unsuitable for children. New editions for the various age levels should be printed in which all that is cruel will be eliminated or at least modified. It is not necessary . . for tortures and murders to occur wholesale." In contrast, consider the attitude of conservative present-day psychoanalysts toward the murder and horror "comic" books, compared with which Grimm's fairy tales were child's play. One of the leaders of the conservative psychoanalytic school has said that these millions of unbelievably cruel comic books should not be criticized because they are "part of the American scene." And the psychiatric apologists for "comic" books have made ample use of latter-day theories about the need to satisfy inborn aggressive instincts, disregarding the observations and experiences of countless mothers who have to deal with reality.

Surely if a psychotherapist believes that aggression is inborn and its future course mechanically determined by childhood experiences, he cannot carry out a prolonged psychoanalysis on a patient without this idea of his being reflected in the results. I have for years collected and studied the effects on people of prolonged conservative psychoanalytic treatment, and the unattractive truth is that these "ex-" patients are among the most aggressive people to be found.

FREUD'S BIRTHPLACE still stands in Freiburg. A plaque honoring him now hangs beneath roof.

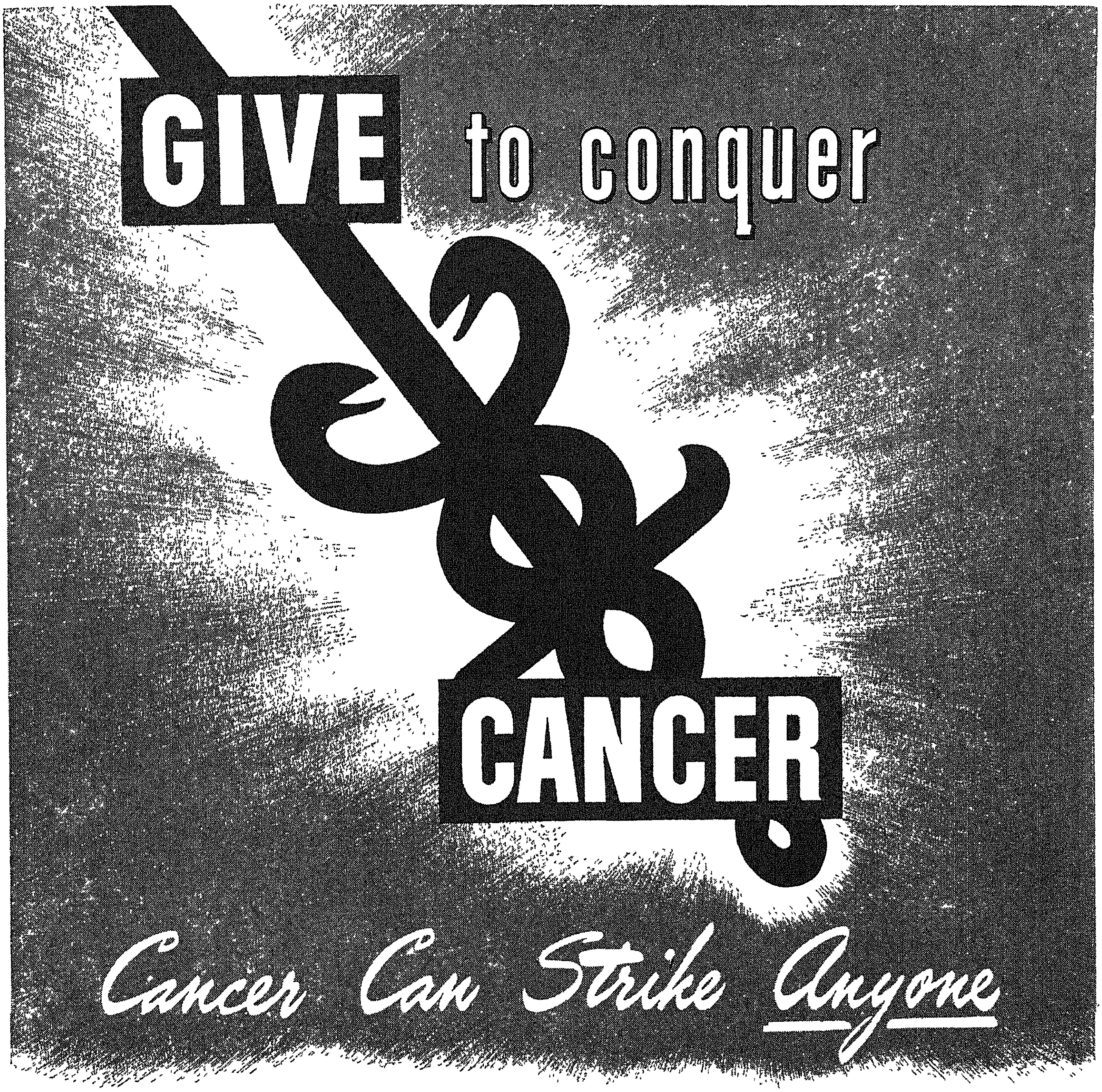
THE great discovery of psychoanalysis was the discovery of the individual. The great error of late orthodox psychoanalysis is to see the problems, the processes and the solutions only within the individual. Inasmuch as the individual from the very beginning grows and matures in a social medium, the disregard of social processes mars the theory and in practice may have disastrous effects on the individual. Freud taught us to understand the many early difficulties between parents and child. But they also occur in the context of the larger society, and the social position of the mother, the father and the child is indispensable for understanding the individual difficulties

It is significant how often, and in what crucial places, in this brief *Outline* Freud refers to race, heredity and the primeval phylogenetic element. He speaks of "racial tradition," and differentiates it from "social milieu." But no race as such has a tradition except as determined by its "social milieu." Here again Freud comes close to those existentialists who invoke "the call of our ancestors " The whole concept of race in the sense in which Freud uses it includes the idea of higher and lower races. A. A. Brill, the leader of the old-style Freudian school in the U. S., wrote in his *Lectures on Psychoanalytic Psychiatry* in 1946· "If you go to a neighborhood like Harlem, where the colored race predominates, you will be immediately impressed —even 'infected'—by the vivid emotional emanation. The Negroes as a race are syntonic [extrovert]: they are very accessible, very ready to talk if you give them the slightest encouragement." Thus an overindividualistic orientation, disregarding social realities, leads to completely false assumptions and conclusions.

We psychoanalysts who wish to guard the true heritage of Freud and develop it in a truly progressive manner do not visualize the future scientific development of psychoanalysis in terms of a formalistic allegiance to the dogmatic doctrine as it stands. One must reconstruct Freud's work on the basis of a realistic philosophy, of newer and broader clinical observations, and on the full utilization of the experiences of mankind during the last two decades. Neglect of the social element in psychoanalysis is based in large part on the too-mechanical separation of biological and social. Such a psychological phenomenon as the Oedipus complex gains its real force from the very fact that it indicates both the social and the biological points of greatest tension. It is significant that the place where Freud's *Outline* breaks off and remains a fragment is a discussion of the super-ego, which is derived from the Oedipus complex and, as Freud says, is "between the id and the external world "

The patient who comes to the therapist has an underlying emotional attitude not very different from that of the tribesman who went to a medicine man. He wants the evil to be exorcised, he wants help. The medicine man gave psychotherapeutic help according to that stage of civilization Psychotherapy must change with the changing conditions. Too many patients who go to conservative psychoanalysts now learn at great expense of time and money the details of how roads are built. But that is not what they need They need to be shown the right road The patient's trouble is that he is bound to the past. It is my firm belief that the therapist can help to break that spell only if he is bound to the future.

Fredric Wertham, author of The Show of Violence, *is president of the Association for the Advancement of Psychotherapy.*


GIVE to conquer
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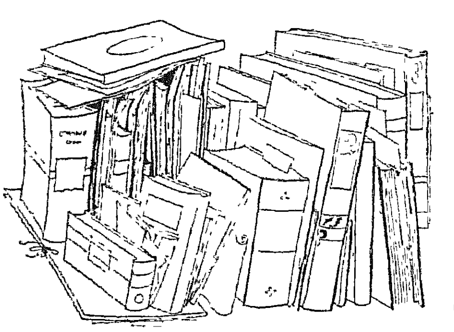


BOOKS

The history of maps: a thread running through the history of everything else

by James R. Newman

THE STORY OF MAPS, by Lloyd A Brown. Little, Brown & Co. ($7.50).

THE fear, the greed and the secrecy that often sway human thought and action are nowhere more plainly exhibited than in the history of cartography. Maps have long been associated with military intelligence and national security, because they might disclose to an enemy or competitor how to get where he wanted to go and what he would find when he got there. Ancient peoples guarded their maps, unreliable though they were, as closely as vestal virgins. The Emperor Augustus, having ordered a survey of his domain, had the maps locked up in the "innermost vault of the palace" and distributed only to generals and to the "schools of the provinces for educational purposes." There is a story of a Carthaginian sea captain who, to prevent a pursuing Roman squadron from capturing his logs and charts, "ran his ship on the rocks and drowned his crew"

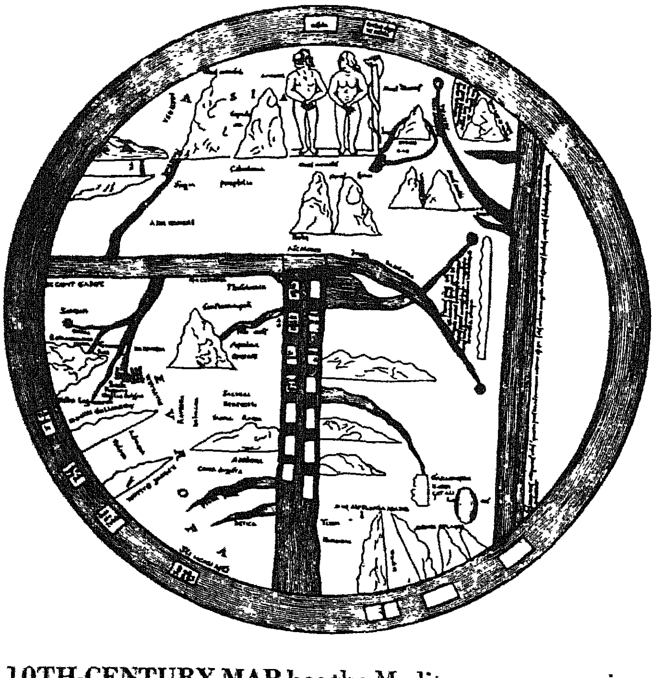
The theme persists through the years. An Englishman, Robert Thorne, subject of Henry VIII, cautioned a friend to whom he sent a "Carde" (chart), spirited out of Seville, that it was "not to be shewed or communicated" since it contained "secretes," especially those "touching the short way to the spicerie by our Seas." The Dutch East India Company labeled its matchless map collection "Secret Atlas." The Spaniards weighted their charts with lead so that they would sink when thrown overboard and thus not fall into the hands of those anxious to cut into the rich Spanish trade. Apparently the contemporary secrets paranoia is a long-established, congenital disease.

I found these facts in Lloyd A. Brown's *Story of Maps,* a handsomely designed, superbly illustrated volume, containing a detailed account of the mapping of the world, the men who did it, their product, methods, troubles, mistakes and successes. It is an absorbing survey.

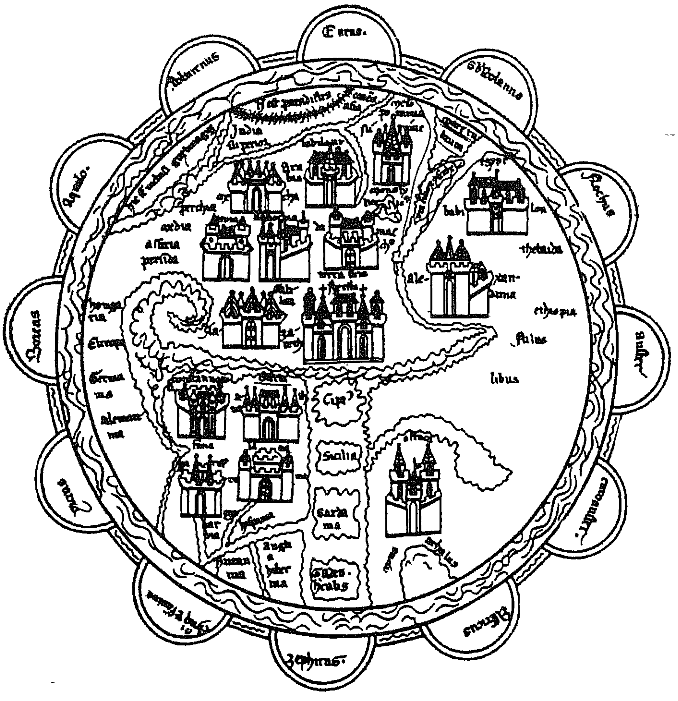
The history of maps, as unfolded in Mr. Brown's scholarly and readable study, is more than a history of maps. It is a history—as reflected in the evolution of maps—of science, theology, exploration, commerce and conquest. Each early map "is a story in itself, often incorporating a little folklore and philosophy, some art both good and bad, and a smattering of scientific fact." Later maps evince more of fact and less of folklore, but social, economic and political circumstance continue to produce their effect at the drawing board.

Brown's story begins with the Babylonians. The star data gathered by shepherds and priests furnished the rudiments of astronomy, a science upon which cartography has always been dependent.

From the reign of Sargon of Akkad, 2300 B.C., there are preserved clay tablet land-tax maps, Babylonian ground plans and surveying notes. Other extant maps precede by more than a thousand years the work of Anaximander and later Greeks who set the science of cartography on a sound theoretical basis. Anaximander "taught, if he did not discover, the obliquity of the ecliptic," and introduced into Greece the gnomon (a vertical shaft for measuring the altitude of the sun) and the sundial. Pythagoras provided the keystone of cartography with his conjecture—how he arrived at it no one knows—that the earth is a sphere Aristarchus of Samos, a distinguished mathematician, was the first, according to Sir Thomas Heath, to put forward the heliocentric hypothesis, which crossed Christian theology by relegating man to his proper place in the universe. It be-



10TH-CENTURY MAP has the Mediterranean running from center to bottom. At left is Europe; at right is Africa. Paradise and Eden (*top*) are in the Far East.



14TH-CENTURY MAP is roughly similar. Greece and Rome are to the left of Mediterranean. Britain and Ireland are near bottom. Map is surrounded by 12 winds.

came a source of unending dispute during the period when the Church rejected as heretical any inconvenient theory not derivable from Scriptures or the sacred writings of Aristotle.

Hipparchus, the astronomer and mathematician, added richly to cartography by his theoretical and observational results. He set the precedent of relating "climate to celestial phenomena," divided the sphere into 360 parts, fixed the length of the solar and sidereal years, noted the steady retrogression of the equinox among the stars, proposed the use of a network of parallels and meridians, assembled a magnificent star catalogue—to mention only some of his labors. "One of the most astonishing men of antiquity . . . and the greatest of all in the sciences which are not purely speculative . . ." as Delambre said of him.

Perhaps the crown of these achievements by the Greek philosophers was the measurement of the circumference of the earth by Eratosthenes of Cyrene, born 276 B.C. With no better instruments at hand than a gnomon and an astrolabe, and only a few facts, such as that the linear distance from Alexandria to Syenê in Libya was known to be 500 miles and that at the time of the summer solstice the sun was directly overhead at midday in Syenê, he arrived at the remarkable estimate of 25,000 miles. (At the equator, according to Herschel's famous measurement, the circumference is 24,899 English miles.) Apart from his versatility in science and philosophy, Eratosthenes was apparently also a man of social sense. The maps of his time, besides other crudities and misinformation (the geographer Pytheas, for example, disclosed that north of Thule, an island itself north of Britain, "there was no longer a distinction between earth, sea and air . . . [but] a weird combination of the three, a kind of gelatinous suspension similar to a jellyfish," which made navigation difficult), usually divided mankind into two groups, Greeks and Barbarians. Eratosthenes, as Strabo, the chronicler of the period, tells us, "thought it would be more sensible to divide them according to behavior, because not all Barbarians were bad any more than all Greeks were noble."

The *Geography* of Strabo was the "climax" to the first great period of map-making. It presented the earth as a globe, incorporated a body of dependable astronomical information, and supplied a scattering of reliable data on climate, population, customs, crops and topography. What was of greater importance, Strabo had considered, not without useful results, some of the difficulties of projection and was fully conversant with the concept of fixing location by means of parallels and converging meridians. The *Geography* also gave currency to a vast quantity of misinformation, including at least one item of consequence, namely Poseidonius' "improvement" on Eratosthenes' measurement of the earth's circumference. Poseidonius gave this as 18,000 miles, a datum which Strabo copied and Claudius Ptolemy "perpetuated" in his maps. For 1,500 years this estimate hampered geography, exploration and commerce and undoubtedly consigned numberless mariners to a damp grave. Columbus, however, was prompted by this error to try to reach the Indies by sailing westward: the Western sea, thus underestimated, "did not look too broad or too forbidding" He turned for authority to the *Almagest* and *Geographia* of Ptolemy, whose writings, theories and maps, for more than a dozen centuries, were the basis of what men knew about the world, their guides to the exploration of land, sea and sky.

Ptolemy was a geographer, mathematician, astronomer and cartographer. In all these fields he was less of an innovator than a systematizer, but his contributions must not be underestimated. At any rate he turned mapping into a branch of learning deserving the name of science. He perfected trigonometry and greatly extended the applications of astronomy to cartography. Many of his map legends and signs remain in standard use; "he originated the practice of orienting maps so that the north is at the top and the east to the right"; the conical and modified spherical projections were his inventions, and the orthographic and stereographic systems were first developed in his atlas. To be sure, he perpetrated his share of blunders, even apart from adopting Poseidonius' erroneous calculations. Yet some of his mistakes, as Brown suggests, appear to have been the result of the same social aberration, secrecy, to which I alluded earlier. The fact that the distances given in Ptolemy's tables for the Mediterranean countries are "erroneous beyond reason"—the Romans having accurately established these itineraries—has long perplexed historians. Ptolemy, however, was a scientist and scholar, not a military man, and it is doubtful (says Brown) that he would have had access to information the Romans regarded as "essential to the national security."

The Middle Ages, on the whole, were no better for map-makers than for any others preferring the empirical advancement of knowledge to the interpretation of what the long dead had written while alive. Cosmas of Alexandria, surnamed Indicopleustes, a Christian, a traveling salesman, and, by avocation, a cosmogonist, is a fair example of the medieval exegetes. Cosmas was a man of common sense with no taste for radical ideas. His religious humility led him to refer to his "stammering and unready lips" and to trust to the wisdom of the Lord. This failed him though his lips did not. Besides his memoirs he issued a work entitled *Christian Topography,* from

which, because it is not atypical of the age, I offer a few examples. Having compared the world to the First Tabernacle—including the candlestick as equivalent to the "luminaries of heaven," the table to the earth, and the "shewbread" to the earth's fruits—Cosmas went on to explain that the earth was flat and twice as long (from east to west) as it was broad. The earth was "suspended, as Job said, on nothing, but was founded on God's stability." The "vault of heaven was 'glued' to the earth along its extremities. . . . There was only one *face* of the earth . . . namely, that which we dwell on. How could we use the God-given power to tread on scorpions and serpents if we walked upside down?"

There is something about modern nationalism, not to say xenophobia, uncannily foreshadowed by Indicopleustes "Pagans," he said, "do not blush to affirm that there are people who live on the under surface of the earth. . . . But should one wish to examine more elaborately the question of the Antipodes, he would easily find them to be old wives' fables. For if two men on opposite sides placed the soles of their feet against each . . . how could both be found standing upright? The one would assuredly be found in the natural upright position, and the other, contrary to nature, head downward. Such notions are opposed to reason, and alien to our nature and condition."

From this darkness of Gog and Magog, the light of a rational body of knowledge nevertheless began to emerge. The fabulous journeys of the Messers Polo, the maritime ventures of Venice, Genoa and the Hanseatic League, the development of towns and the rise of a merchant middle class, the Reformation, the scientific discoveries of Galileo, Brahe, Copernicus, Kepler and Gilbert, the invention of printing, of the telescope and other astronomical and navigational instruments, all contributed to the advance of geography and map-making. Even the Church, bent on the "militant diffusion of Christianity," needed better maps for its missionaries and crusades if they were to achieve their destination. "Navigation," wrote Thomas Blundeville, "is an Art which teacheth by true and unfallible rules, how to governe and direct a Ship, Safely, rightly and in shortest time. I say heere safely so farre as it lyeth in man's power to performe."

The maps of Gerard Mercator, 16th-century Flemish cartographer, engraver and instrument-maker, enormously facilitated the practice of this perilous art. His famous projection may be explained as follows. If a balloon covered with a network of parallels and meridians is placed inside a cylinder and inflated, the expansion will cause the curved meridians to straighten and, together with the parallels of latitude, gradually to flatten against the cylinder walls. If the network has been inked, when the cylinder is unrolled you will find impressed on its interior walls a Mercator projection. This conformal projection (in which angles are preserved) of a sphere onto a plane surface, for all its distortion of shapes and distances at the extremities, was the "answer to a mariner's prayer." It was geometrically accurate, its distortions were proportional and affected regions little frequented by ships engaged in trade, exploration or war. There is no such thing, writes Brown, as an all-purpose map; but as an aid to navigation "the Mercator chart has never been approached."

The 16th, 17th and 18th centuries produced a series of incomparable atlases. They included Mercator's own celebrated work which made the word "atlas" a synonym for a map collection; the *Spieghel der Zeevaerdt* (The Mariner's Mirror) compiled by Lucas Janssz Wagenhaer, the *Theatrum Orbis Terrarum* of Mercator's friend Ortelius, and the *Cosmographiae Introductis* by the Swiss Waldseemüller, who first used the name America in his maps. (But for his choice, I suppose, a noted present-day board of inquisition might be known as the Un-Vespuccian Activities Committee.) The political consequence of these volumes was profound. Wagenhaer's charts, for example, which provided "concise sailing directions for a hotly contested area," reached the market, as Brown points out, when European powers and the Queen of England most needed them.

Besides being useful, the atlases were magnificent specimens of art and bookmaking. They came in library and pocket-size editions, engraved, "diapered" in gold, gorgeously colored with cochineal, copper green, vermilion blue bice, indigo, ultramarine, tincture of myrrh, ivory black, king's yellow and white tartar. The colors were applied to fine, strong paper with a camel's-hair brush and then fixed with egg white. Other necessary equipment included gum-arabic pencils, quicksilver, "Hartes horne," the yolks of "newe laide egges" left standing till "clammy and rotten," lampblack made by "a burnynge torche," "Sal-armoniak," the "joyce of garlike" and horse dung. The embellishments were of endless variety: the East Wind "a youth with puffed and blown cheeks"; the North Wind an old man with "a horrid and terrible look", mountains, towns, roads, rivers, mines, parishes, coastlines with special symbols of their own. Brown's account of these details is among the most entertaining portions of his book.

He describes capably the gradual evolution of astronomical and navigational instruments necessary for the determination of latitude and longitude: the cross staff, telescope, compass, quadrant, sextant and octant, the contributions to cartography of Newton, Huygens and various scientific bodies; the design and construction of accurate

clocks. The persistent search for a reliable method of determining longitude at sea produced its share of fantastic as well as sensible suggestions. Sir Kenelm Digby, for example, invented a "powder of sympathy" which, by a method I shall not attempt to repeat, caused a dog on shipboard to "yelp the hour on the dot." This was not the final answer to the problem of the reliable timekeeper. John Harrison, the Yorkshire carpenter, did better with his famous No. 4 chronometer, which took 50 years to make but lost only one second per month in trials at sea. In pressing his rightful claim to the huge reward of £20,000 offered by Parliament for a dependable chronometer, this "very ingenious and sober man," as a contemporary called him, was the victim of a series of unsurpassed chicaneries perpetrated by scientists and politicians in combination. He got his money, but only after the King had intervened on his behalf, Lord North had petitioned the House, and the redoubtable Fox had threatened to name names. It took 15 years to win the fight.

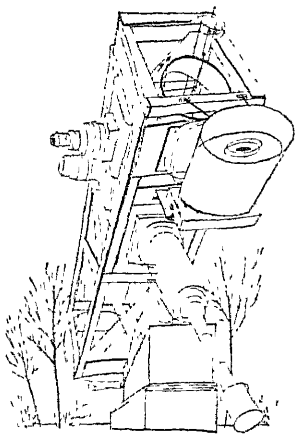
A valuable, richly enjoyable book. I am sorry to say that for all its thoroughness it tells us almost nothing of the maps of primitive societies or of those of the Orient; it skimps the exploits of the Vikings and Phoenicians; contemporary cartography is somewhat hurriedly disposed of; and Mr. Brown is not at his best in explaining for popular comprehension the many-sided problems of projection. But to stress these defects would be, to fall back on a reviewer's cliché, simple ingratitude.

Philosophy for the Future, edited by Roy Wood Sellars, V. J McGill and Marvin Farber. The Macmillan Company ($7.50). A better than average symposium which traces the origins of philosophical materialism, examines its relationship to diverging systems of thought, and argues that modern, or critical, materialism provides the most satisfactory framework for unifying science and philosophy and for turning these activities to the consistent advantage of human society. While a number of the essays are written in the usual viscous vernacular, the contributing scientists and philosophers on the whole present their case impressively, and it is a volume peculiarly welcome in this period marked by a counter-reformation of anti-intellectualism, irrationalism, fear and widespread appeals to orthodoxy and authoritarianism.

Two Memoirs, by John Maynard Keynes. Rupert Hart-Davis (London). A delightful pair of essays by the late John Maynard Keynes who, because of his theory of deficit spending, has become a target of considerable political vilification. One essay describes Keynes' part in the 1919 negotiations to lift the blockade against Germany; it is of the same character as his famous *Economic Consequences of the Peace*. The other essay, entitled "My Early Beliefs," is a brilliant paper, written, as was the other, to be read to a small audience of close friends who shared with Keynes intimate memories of their social and philosophical companionship at Cambridge. "Truth and wit," as David Garnett observes in his brief introduction, "are felt by many to be rather shocking virtues which should appear in public only if they are decently veiled." These virtues, borne along on an effortless prose style, are exhibited here as in all the writings of this many-sided man. The frontispiece photograph showing Bertrand Russell, Keynes and Lytton Strachey in conversation is a gem.

Your Child's Mind and Body, by Flanders Dunbar. Random House ($2 95). An intelligent, unsentimental handbook on the care and repair of children, with primary emphasis on the psychosomatic aspects of their problems. Dr. Dunbar's most persuasive point is that if you have learned to be a good parent to yourself you will be a good parent to your child. She demonstrates this effectively in a variety of situations and by many examples from, presumably, her own practice. Unfortunately she has an uncanny inability to reproduce child-parent dialogues so that both parents and children sound like angels of reasonableness, and the clinical moppets like brighter versions of John Stuart Mill.

High Jungle, by William Beebe. Duell, Sloan and Pearce ($4.50). Dr. Beebe, Director of the Department of Tropical Research of the New York Zoological Society, has led 47 expeditions for animal study to various parts of the world, including the Himalayas and the bottom of the Atlantic His 22nd book, fluent, entertaining and informative, is based on three visits to the Venezuelan Andes, spent mostly at his Rancho Grande Laboratory, an immense, half-finished concrete structure intended as a palace for a Venezuelan dictator, Juan Vicente Gomez. When Gomez died one December day in 1935, the palace workmen promptly dropped their nails, bricks and tools and abandoned the job. By courtesy of the Venezuelan government and a kind oil company, Dr. Beebe's party was given 18 rooms in this structure, situated in the heart of the coastal mountains, for research, living quarters and as home base for field trips. Apart from a somewhat tiresome tendency to attribute human qualities to all organic forms from avocados to wrens, and to splash a subject already rich in color with more color, Dr. Beebe tells his stories well. His chapter on ants is fascinating, as are several of the photographs.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

WHEN the astronomers at Palomar Mountain Observatory announced that the already good mirror of the 200-inch telescope was to be perfected by polishing a few millionths of an inch off its outer 18 inches, many readers wondered how telescope makers can accurately measure the removal of such small amounts.

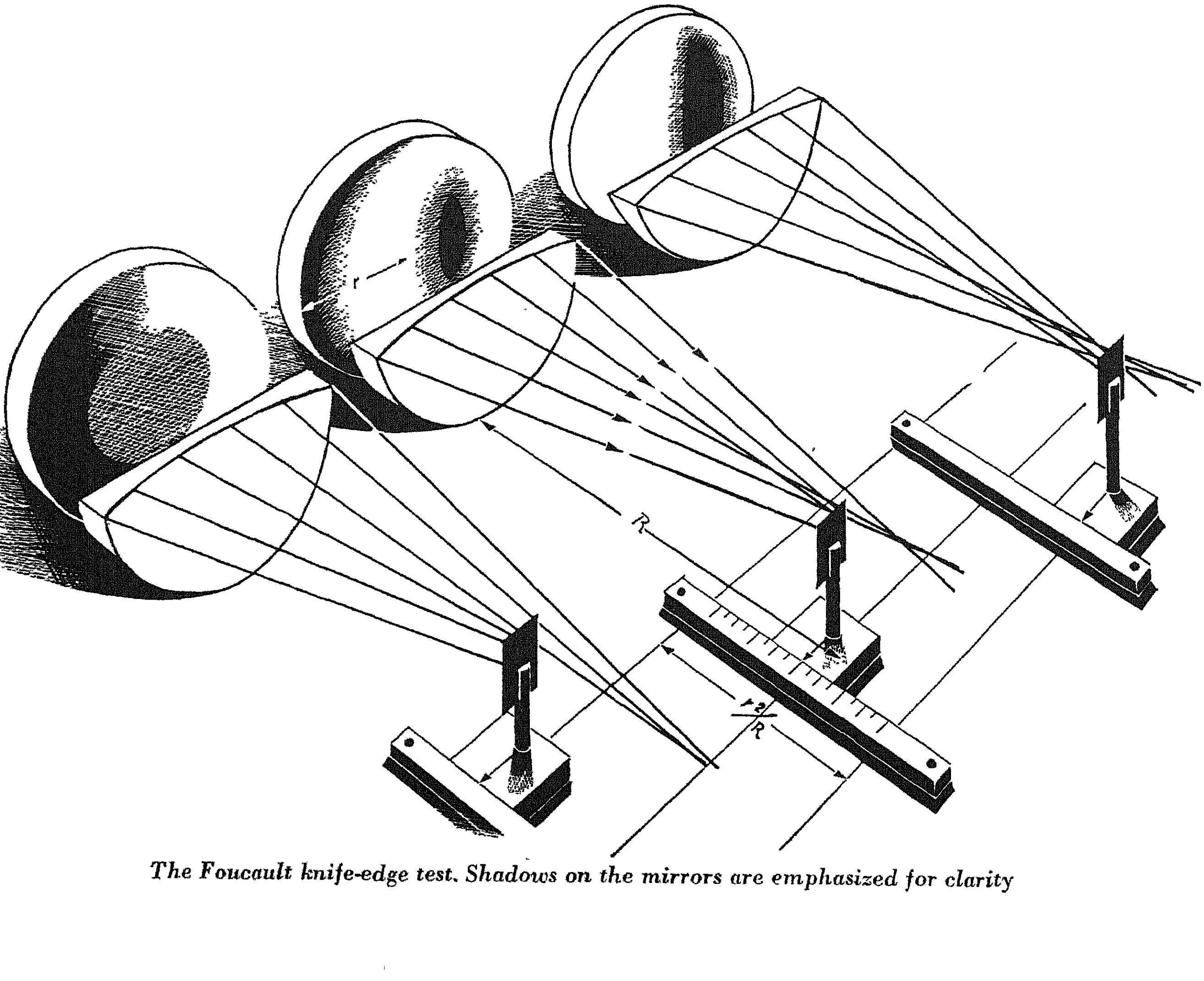
Such measurements are too delicate to be made with mechanical devices. Instead, a special kind of weightless and inflexible indicating pointer is used—rays of light. The drawing at the bottom of this page shows in principle how such refined curves are measured. The following explanation is addressed not to telescope makers, who already understand its substance, but to general readers. For simplification some corners can be cut without harm.

Of the three arrangements shown side by side in the drawing, only the central one need be noted at first. The three disks in the background may be ignored for the present.

In the drawing, rays of light are directed at the mirror from in front of it, for simplicity these rays are not shown. If the mirror is spherical, *i.e.*, if a large sphere would fit against it, these rays will all be reflected to cross one another at some single point in space. The method used to determine this is to locate representative reflected rays by means of a movable feeler. For this a razor blade on a little pedestal serves about as well as would more complicated apparatus. This "knife-edge" is slowly moved by hand from left to right, cutting off ray after ray, each of which is thus identified with the part of the mirror from which it is reflected. At a distance of a few feet these pointers of light greatly multiply the mirror's irregularities. Thus a millionth-of-an-inch change of angle on the mirror deflects the light-ray pointer an easily detectable hundredth of an inch at knife-edge distance.

One deviation from the sphere that is actually desirable is the paraboloid. The mirror maker knows that he has deepened his sphere the few millionths of an inch needed to make it a paraboloid when the rays reflected from the inner part of the mirror (*left-hand mirror*) cross one another nearer the mirror than those reflected from the outer part (*right-hand mirror*) by a distance r^2/R, where r is the half-diameter of the mirror and R is the radius of its curvature. The actual distance involved is seldom more than a fraction of an inch. The scale of things near the knife-edge is exaggerated in the drawing.

An auxiliary method used by mirror makers for keeping track of the curve between spells of work is to set the mirror up on edge, as shown in the representations in the background, place the eye close behind the knife-edge, and



The Foucault knife-edge test. Shadows on the mirrors are emphasized for clarity

move the knife-edge partly across the reflected rays. A paraboloidal mirror will then show over its surface a pattern of lights and shadows like the one in the central representation. The origin of this peculiar pattern—new moon on the left, oval on the right, with subtle intergradations—will be seen if the six typical rays shown are traced from the mirror to the knife-edge. Some rays are cut off by the knife-edge, and the corresponding areas on the mirror look dark. Other rays, swung farther right by a slightly different angle on another part of the mirror, pass the knife-edge and enter the eye, making the corresponding part of the mirror appear bright. The patterns of shadows that are found on telescope mirrors as polishing progresses, some of them indicating excellent shape, others indicating evil shapes too numerous to mention, soon become as familiar to the worker as his own features

This exquisite and most revealing method is the "Foucault test" invented by the French physicist and telescope maker Léon Foucault, who described it in 1859. It has been said that the Foucault test changed mirror making from an art to a science. This is true, but the remainder of the present article will show that mirror makers before Foucault were not so much in the dark as such a statement might imply.

IN 1773, 86 years before Foucault revealed his knife-edge test, William Herschel began making mirrors of speculum metal and of glass, ending about 1789 with a 40-inch mirror. Constance A. Lubbock, in *The Herschel Chronicle*, tells how Herschel tested his mirrors. Placing them temporarily in a telescope, he successively isolated three zones with masks and located the focus of each. He then figured the mirror till all three zones had an equal focal length. In 1924 the British amateur telescope maker W. H. Steavenson tested a dozen of these old mirrors that had been preserved by Herschel's descendants in the family home at Slough, 20 miles west of London. Steavenson's tests, made by the Foucault method, which was of course wholly unknown to Herschel, show that while Herschel sometimes grossly overcorrected his mirrors, he often obtained proper correction. Steavenson's findings on 12 of Herschel's mirrors revealed the following conditions.

Speculum mirror, 9-inch *f*7 Gregorian. Figure very even, one high zone.

Speculum mirror, 7-inch *f*11 Gregorian. Figure very even, except for a narrow shallow zone.

Speculum mirror, 6-inch *f*5.6. Figure only very slightly uneven, but 414 per cent correction.

Glass mirror, 6½-inch *f*13. Good polish. Even figure so closely spherical that no zonal test was made.

Glass mirror, 8½-inch *f*14. Figure very even, except for three narrow zones. Too nearly spherical for zonal test.

Glass mirror, 6½-inch *f*13.5. Even figure, except for two narrow zones, but 1,015 per cent correction.

Speculum mirror, 5-inch *f*3.6. Figure even; no zones. Parabolic shadow, but too short a focus for testing apparatus

Speculum mirror, 9-inch *f*8. Very even, regular figure. Too nearly spherical for zonal test.

Speculum mirror, 8.85-inch *f*14. Very smooth, nearly spherical and regular, except for a deep, broad zone spanning 40 per cent of the mirror's radius.

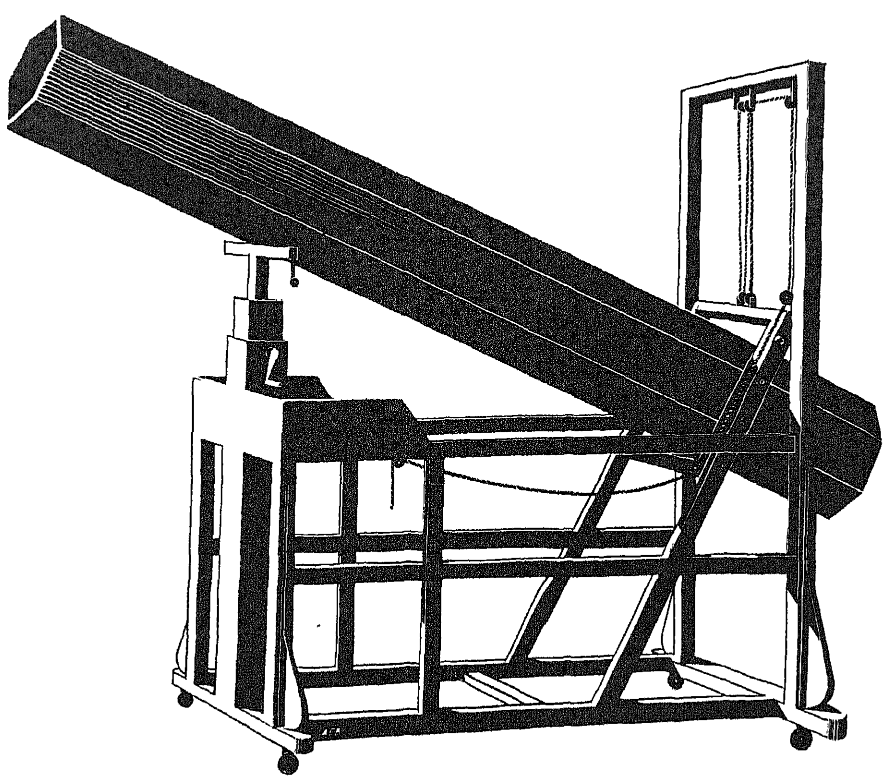
Glass mirror, 9-inch *f*13, ⅓-inch thick. Too violently distorted when stood on edge to permit testing.

Speculum mirror, 8.8-inch *f*13. Very even, except for three zones. No zonal test made because of nearness to sphericity.

Speculum mirror, 6.1-inch *f*13.9. A beautifully smooth curve from center to edge without sign of zones or other irregularities. Correction 62 per cent.

In his book *The Telescope,* Louis Bell mentions Herschel's so-called "7-foot" (Herschel designated telescopes by their focal length), a Newtonian reflector with which he discovered Uranus. The drawing on page 62 depicts a Herschel 7-foot now at Oxford University. Steavenson tested and used another Herschel 7-foot which he found among the mirrors, 30 elliptical Newtonian flats, 9 Gregorian secondaries, 48 eyepieces, 10 micrometers and 33 miscellaneous pieces of apparatus preserved at Slough. (Later he described them all in the *Transactions of the Optical Society*, Volume 26, pages 210-236.) The last mirror in the list above, the one with 62 per cent correction and "a beautifully smooth curve," was the one in the 7-foot tested by Steavenson. "This," Steavenson writes, "is the only complete instrument in the collection. It stands in the entrance hall of Observatory House, and is in good condition and fair working order. Both tube and mounting are of mahogany, the former being of octagonal section, like all Herschel's smaller telescopes. Both mirror and flat were much tarnished, the cover of the former being far from airtight, and the latter being without a cover of any kind. A good deal of the tarnish on both was removed by means of lemon juice, and a useful proportion of the original reflectivity was thus restored.

"The large speculum, of diameter 6.2 inches and focal length 7 feet 2¾ inches, was removed from the tube and subjected to a Foucault test. The latter showed the figure to be beautifully regular, without a trace of rings. A measurement of the zones suggested the presence of a very slight degree of undercorrection, the test being made under conditions of constant temperature. The mirror was then replaced in the tube and



Sir William Herschel's famous "7-foot" reflecting telescope

the whole telescope taken out of doors for actual testing on celestial objects. For this one of Herschel's own eyepieces was used, a single biconvex lens giving a power of 361. No observations were made until the telescope had stood in the open air for several hours, but even with this precaution the effect on the mirror of a steadily falling temperature was very marked, for whereas the figure had appeared slightly but definitely undercorrected at a constant temperature, it was now found to have passed through the paraboloid to a state of slight overcorrection. However, definite rings were visible in the expanded images of stars on both sides of the focus, while at the latter itself there was nothing to indicate any departure from perfect correction.

"Apart from the inevitable color and loss of definition in the peripheral portions of the field (due to the form of the eyepiece), the performance of the telescope was most admirable. Of course the light grasp was deficient, owing to tarnish, but it did not seem inferior to that of a 3-inch refractor, the companion of the Pole Star being easily seen. The detail on the Moon was as fine as that shown by any modern reflector or refractor of similar aperture. The shape of the second peak in Tycho was well made out and the third peak, to the west of it, could just be seen. The central craterlet in Plato was clearly seen as such, and one or two of the minute craterlets on the west half of the floor of Clavius were definitely visible. This is about as much, as regards detail, as a modern 6-inch refractor will do. Venus and Jupiter were exquisitely defined. Arcturus showed a neat disk with diffraction rings, which is more than is brought out by many modern reflectors.

"It has often been suggested that Herschel's instruments, though marking a great advance on previous efforts, would not be accounted good according to present-day standards. Anyone holding such an opinion would, I think, feel inclined to revise it after a glance through this beautiful 7-foot telescope."

NOW we drop back a third of a century. In his *Compleat System of Opticks,* published at Cambridge, England, in 1738 (the year Herschel was born), Robert Smith gave instructions for speculum making that were destined to be the beginner's guide for Herschel the amateur 35 years later. To find the center of curvature of a speculum Smith's method was to set it on edge opposite a candle. Selecting a tiny pinhole near the edge of the tin, he shifted candle and tin until he could simultaneously focus in the eyepiece the edge of the tin and the image of the pinhole reflected from the speculum. How he then tested the speculum is described in his book thus:

"You will now also judge of the perfection of the spherical figure of your metal by the distinctness with which you see the representations of the holes, with their raggedness, dusts and small hairs sticking in them; and you will be able to judge of this more exactly and likewise to discover the particular defects of your speculum, by placing the eyeglass so as to see one of the smallest

holes in or near its axis; and by turns shoving the eye-glass a little forward towards the speculum and pulling it away from it by turns, letting the candle and plate stand still in the mean time. By this means you will observe in what manner the light from the metal comes to a point, to form the images, and opens again after it has past it. If the area of the light, just as it comes to or parts from the point, appears not round but oval, squarish, or triangular &c. it is a sign that the sections of the specular surface, through several diameters of it, have not the same curvature. If the light, just before it comes to a point, have a brighter circle round the circumference, and a greater darkness near the center, than after it has crossed and is parting again; the surface is more curve towards the circumference and flatter about the center, *like that of a prolate spheroid* round the extremities of its axis, and the ill effects of this figure will be more sensible when it comes to be used in the telescope. But if the light appears more hazy and undefined near the edges, and brighter in the middle before its meeting than afterwards, the metal is then more curve at its center and less towards the circumference; and if it be in a proper degree, may probably come near the true parabolick figure. *But the skill to judge* well of this must be acquired by observation.

"In performing the foregoing examination, the image must be reflected back as near the hole it self as the eye's approach to the candle will admit of, that the obliquity of the reflection may not occasion any sensible errors: in order to which the eye should be skreened from the candle, and the glaring light which may disturb the observation may be still more effectually shut off, by placing a plate, with a small hole in it, in the *focus of the eye-glass which is next the* eye. *A* is the speculum, *B* the candle and plate with the small holes, *C* the cell with the eye-glass and plate behind it.

"Instead of the flame of the candle and plate with small holes, I sometimes made use of a piece of glass thick stuck with globules of quicksilver, strained through a leather and let to fall on it in a dew; placing this glass near a window and the speculum at a distance on the side of the room, being it self and every thing about it as much in the dark as can be. The light of the window reflected from the globules of mercury, appearing as so many stars, serves instead of the small *holes, with this advantage, that the re*flection from the metal may be very near at right angles."

ANOTHER example of pre-Foucault methods of testing telescope mirrors is from the *Philosophical Transactions of the Royal Society of London,* Volume 130, Part 2 (1840), in which Lord Oxmanton, the third Earl of Rosse, born William Parsons, describes his method of testing as used on a 36-inch speculum. The dial plate of a watch is suspended from a high tower, face downward. At the bottom of the same tower is the speculum, face up on its machine. Lord Rosse used masks "as Mudge did."

How Mudge used masks was described in the same periodical, Volume 67, page 335, in a paper that Mudge delivered in March, 1777. He placed a separating mask having one eighth the diameter of the mirror opposite a zone midway between the center and the edge, and tested first the inner zone and then the outer one both for definition and for coincidence of focus. If the two images were equally sharp and of equal focus "the speculum," he said, "is perfect and of true parabolic curve."

Foucault described his test in 1859. Two years later William Herschel's son Sir John, in his *Encyclopaedia Britannica* article on the telescope, reprinted as a book, *The Telescope,* in 1861, briefly outlines Foucault's "peculiar method." But he prefers the diffraction-ring test (*Amateur Telescope Making,* page 428), supplemented by his father's test of matching three zones for focus on the stars, and the watch-dial test of Lord Rosse. Thus the older mirror makers did not rush at once to use Foucault's test. In 1887 With, the English professional, wrote the following about a mirror. "Among my choicest of the choicest, I find one recorded thus: '8½ focus 5 feet 3 inches. Absolute Perfection, Not for Sale.'" F. J. Hargreaves, Britain's foremost optician, who was once an amateur, states in the *Journal of the British Astronomical Association* that With had no knowledge of Foucault's knife-edge test. Hargreaves found in 1941 that this mirror "gave images as nearly perfect as any I have ever seen, even with a magnification of 500 diameters." He tested it by the Foucault method and found that it "showed no imperfection, apart from a narrow turned-down edge."

Hargreaves' article was shown in 1941 to Russell Porter, who jotted on the page, "Anderson judges the 200-inch mirror by inspecting image of pinhole as much as by knife-edge test."

Nothing said above may be taken as in any sense derogatory to the knife-edge test, best of all tests. The evidence assembled may, however, show that workers before Foucault's time were not so much in the dark as we sometimes assume.

In *Amateur Telescope Making—Advanced,* page 48, Everest states that he once made a mirror only by "feel" in the grinding and by the appearance of the polish as it came up. Yet the mirror came out 50 per cent corrected. A winter's contest within a group of amateurs might well be to see who can make the best mirror exclusively by the methods available before Foucault.

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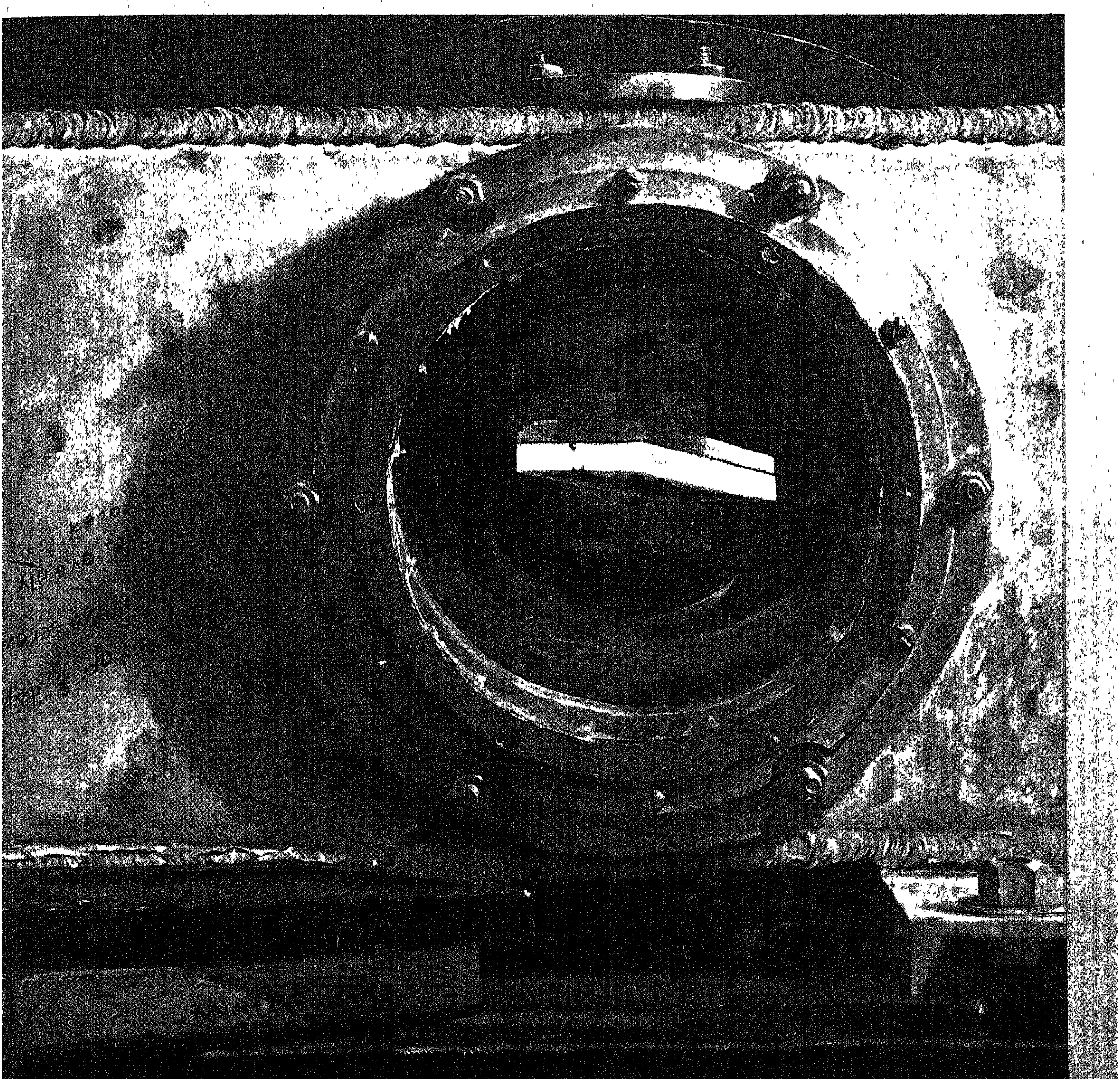
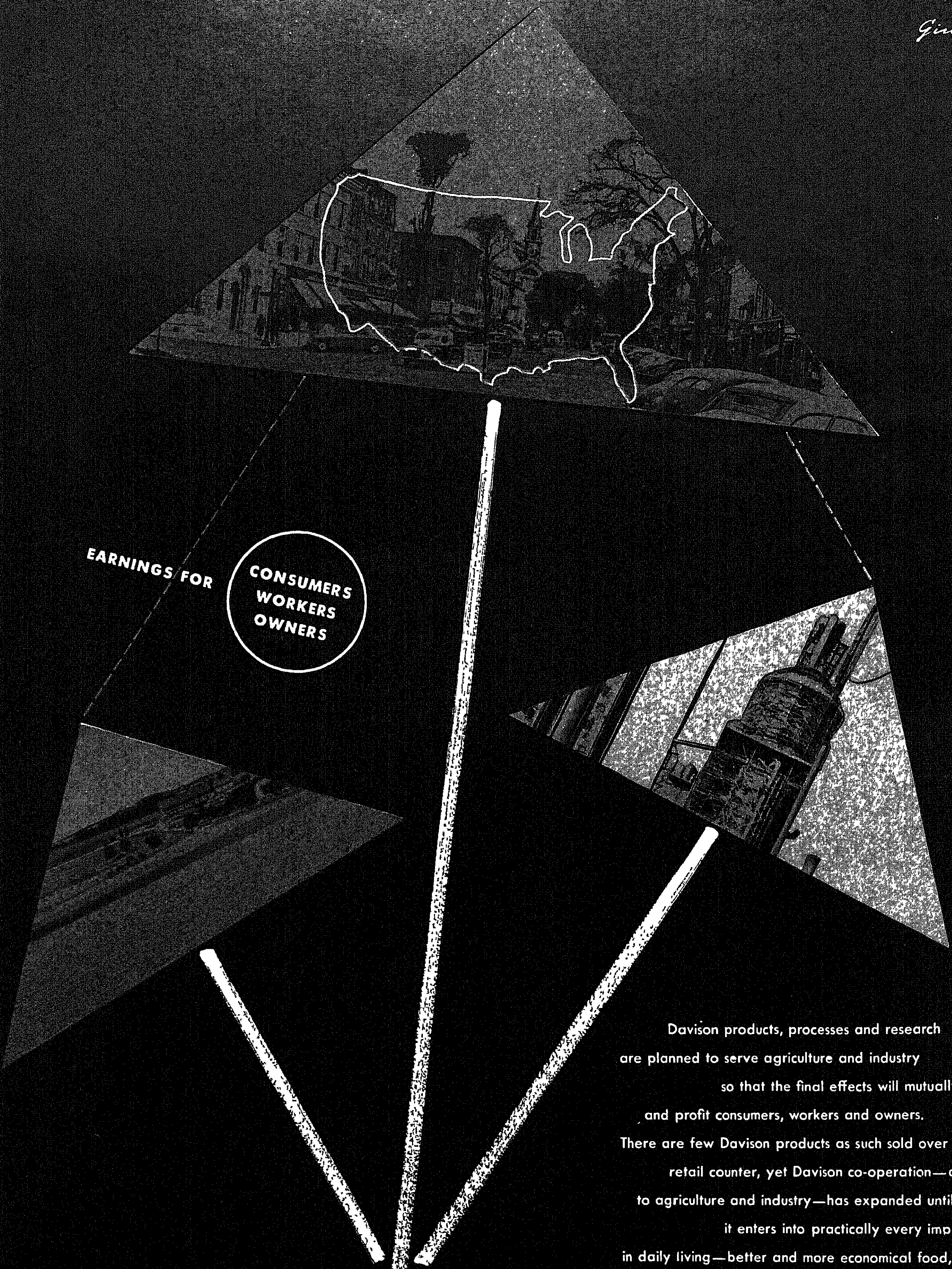


SHOCK WAVE RESEARCH

FIFTY CENTS
75 CENTS OUTSIDE THE AMERICAS

November 1949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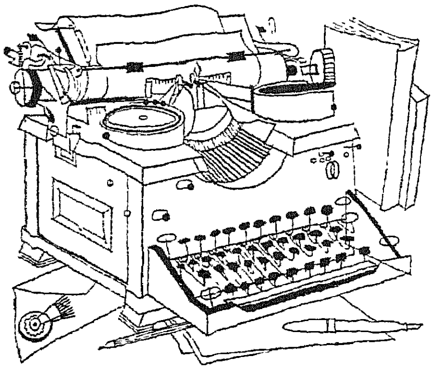

Sirs:

As an old Woods Holer, permit me to say how much I enjoyed your article on Woods Hole. But what this note is really about is the name of the place. When I was a student in the Marine Biological Laboratory, for some reason now forgotten I became curious about that name. I think someone told me that it really should be Woods Holl, which is evidently the story you picked up. In any case, I discovered that many years ago there was a burning and emotional controversy about the name. The polemical literature of this little tempest appeared in New Bedford and other papers if my memory is correct. Certainly there were three candidates for the name, the two above and Woods Hall.

After spending the better part of two days probing into this subject, I decided to leave further scholarly endeavor to others. It seemed to me largely a paper argument in which neither side had any real evidence.

But it has occurred to me and others afterwards that all the weight of probability favors Woods Hole as the name given to the place where a boat could get between the mainland of the Cape and the first of the Elizabeth Islands. All the other channels between the Elizabeth Islands are called Holes, *e g.*, Robinson's Hole, which is the only one I can recall by name. No special theory is needed to explain Woods Hole as a corruption of Woods Holl.

GAIRDNER MOMENT

Department of Biology
Goucher College
Baltimore, Md.

Sirs:

In his article on Galileo (*Scientific American*, August) I. Bernard Cohen mentions Galileo's discovery "that the planet Venus has phases like those of the moon." It might be of interest that Galileo published his discovery in a letter of December 11, 1610, addressed to the famous astronomer Kepler, by using an anagram.

What Galileo wrote to Kepler was the following sentence, which does not make any sense at all. "*Haec immatura a me jam frustra leguntur o.y*" Translated from Latin. "I try in vain to read those immature things o.y." But by changing the order of the letters of this sentence one gets the following hexameter. "*Cynthiae figuras aemulatur mater amorum.*" Translated from Latin. "The Mother of Love (Venus) imitates the phases of Cynthia (mythological name for the moon)."

It seems to have been a custom among scholars in Galileo's time to communicate scientific discoveries in the form of anagrams—possibly to make sure of the priority of a discovery without committing themselves.

WALTER J. BRUNS

Syracuse, N. Y.

Sirs

James R. Newman's recent review of Sir Charles Sherrington's book on Goethe as a scientist should not pass without comment. Readers who are unfamiliar with the facts—and I presume most readers are—must think that a powerful lobby is at work to sell Goethe to the American people as a scientist in the modern sense. Responsible interpreters do not make such claims. It has been settled for a long time that Goethe was entirely mistaken in his criticism of Newton, that he understood neither the experimental method nor the use of mathematics in physical theory, and that his biological theories were interesting ideas which did not stand the test of experience. Goethe's modern standard-bearers for the most part refer to his work in these fields not in order to claim that his ideas have become part of the established body of science but rather as a manifestation of the vastness of his interests and the unity of his vision of the various aspects of nature and life.

Why this emphasis on what he has not achieved? We do not think it necessary to debunk Dante because he believed that there was a cone inside the earth which was Hell, or that Purgatory was a hill rising out of the water right opposite Jerusalem. Mr. Newman points out that Lavoisier, Lagrange and Laplace were scientifically ahead of Goethe; the same could be said of Roger Bacon in relation to Dante. Yet several pages are given to Dante in George Sarton's *Introduction to the History of Science*. We do not hold it against Shakespeare that his knowledge of geography was grossly defective. Newton was one of the greatest scientists of all time, but he became a mystic in his old age.

Goethe, a century ago almost as famous in this country as he was in Europe (Emerson included him in his *Representative Men*), is almost unknown to Americans today. Why this is so is no mystery. Goethe was primarily a poet. Poetry cannot be transplanted from the climate of one language to that of another, and the number of Americans today who have sufficient command of German—or of any foreign language—to appreciate lyric poetry is very small. Thus there are no more people in a position to appreciate Goethe than can appreciate Homer or Sophocles, Dante or Petrarch, Calderon or Lope de Vega, Pushkin or Lermontov, Baudelaire or Mallarmé.

ROBERT WAELDER, PH.D.

Philadelphia, Pa.

Sirs:

Our Golden Age of physics and mathematics and its astonishing advances has exerted a deep influence on the way we look at the history of science, which itself is continuously changing. This leads to temporary distortions in perspective, as your September issue shows, when the reviewer of Sherrington's book on Goethe exposes in five columns that

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"Goethe was a magniloquent and befuddled bore. . . . The story is easily documented."

Goethe's eminent contemporaries, as the physicist Lichtenberg, the young Schopenhauer, and later the founder of modern pathology, Rudolf Virchow, and the great physicist Helmholtz in his essay on Goethe's "Anticipation of Future Ideas of Natural Science," were by no means victims of hero worship and unaware of Goethe's shortcomings in analytical and mathematical optics, but they recognized the value of Goethe's observations for the psychology of sensory perception—without dogmatically stating, as your writer does, that "scientific progress rests on measurement and number." We cannot help being reminded of Wagner in Faust:

Excuse me! But it is a great delight
To enter in the spirit of the ages and
to see
How once a sage before us thought
and how we
Have brought things on at last to
such a splendid height.

In his time Goethe's biological contributions were not so minor as they may seem to us today. His discovery of the intermaxillary bone ended once for all the last supposed difference between the skulls of animals and men, depriving man of his imagined preferred anatomical position in nature. The ideas of heredity are clearly outlined in his famous teasing verse on his family tree—to be sure not in the jargon of modern biology, but in the language of the 19th century. Even in 1830, in his 80th year, Goethe wrote an excited report on the fundamental discussions in the French Academy between the exact Cuvier and the speculative Saint Hilaire. Freud—who certainly knew that Goethe refused ever to visit an asylum—ascribed the decisive turn in his own career to the young Goethe's enthusiastic essay "On Nature."

Lichtenberg, Schopenhauer, Virchow, Helmholtz, Freud (to cite only a few)—all giant pioneers in creating new sciences of their own—spent a great deal of time on Goethe's life endeavors It seems they did not consider his way of viewing nature as a whole the antiquated, outmoded and useless talk of "a gabby old man." The blind spots, the antipathies and the weaknesses in the life of a genius are often just as instructive and significant to the understanding of the man and his work as his positive contributions. We cannot ignore Sir Isaac Newton's religious speculations, Dostoievski's chauvinism, or Freud's dislike of America. Your reviewer, however, is satisfied to characterize Goethe's most complicated personality sweepingly as "conservative with a rigidity of outlook."

RICHARD D. LOEWENBERG, M.D.

Bakersfield, Calif.

50 AND 100 YEARS AGO

NOVEMBER 1899. "We understand that the signal corps of the army is about to carry out a series of experiments in Washington in connection with the new automobiles which were recently built for the War Department. The experiments are to be made in the country around Fort Myer. An automobile wagon equipped with a set of Marconi sending and receiving apparatus will be dispatched several miles from the fort, and when it reaches its destination it will send a balloon into the air which will carry a vertical wire to the proper height corresponding with the distance over which the messages are to be sent. Another set of apparatus with a vertical wire will be installed on an automobile stationed at the fort."

"We regret to see that aerial navigation has recently claimed another victim, whose death was due to causes precisely similar to those which brought to an untimely end the experiments of the late Herr Lilienthal. Lieutenant Pilcher of the Royal Navy, the latest victim, had been for many years an earnest student of the subject of aerial navigation. His line of investigation was similar to that of Lilienthal and was directed to the development of the soaring machine. It must be confessed that the late tragedy seems to prove that the era of safe artificial flight is yet a long way off."

"Prof. Bergmann, the great surgeon of the Berlin University, states that the healing power of the Roentgen rays are imaginary. The determination of the presence and position of foreign bodies has been extremely successful with the Roentgen rays, as is well known. Their use in connection with broken bones has also been very satisfactory. The hope of discovering, by the aid of the Roentgen rays, the position of bladder and gall stones has not been fulfilled."

"A remarkable collection of films for moving picture machinery are now being developed at the laboratory of Mr. Edison in West Orange. The pictures are of the Klondike and are intended for the exhibit Mr. Edison is to make at the Paris Exposition."

"Prof. Ernest Haeckel, the great German Darwin exponent, was recently thrown from his horse in Rome and seriously injured. He is now 65 years of age."

"At the recent meeting of the British Association, Prof. J. J. Thomson, F. R. S., gave an interesting account of recent researches on the existence of masses smaller than atoms. These experiments indicated that the charge carried by an atom in cathode discharges and similar phenomena is apparently 1,000 times greater than in ordinary electrolysis. Consequently either the atoms become disassociated and only a portion of their mass carries the negative charges of cathode rays, or else the atom can receive a greater charge than is assigned to it in explaining electrolytic phenomena. To discriminate between these two assumptions a method was employed to determine separately the charge carried by a known number of atoms in a case for which the charge per unit mass had the greater value. From this it would appear that electrification seems to consist in the removal from an atom of a small corpuscle, the latter consisting of a very small portion of the mass with a negative charge, while the remainder of the atom possesses a positive charge."

"The autumn meeting of the National Academy of Sciences was held at Columbia University, New York, beginning November 14. Prof. Edward C. Pickering sent a report giving a detailed account of discoveries by photography at Harvard and at the Arequipa Observatory in South America. Several new double stars have been discovered of two classes, those in which both components are luminous and those in which one is dark, the latter class being variable, because of the occasional interposition of the dark component. Several of the double stars have periods of rotation less than two days, one being even less than thirty hours."

NOVEMBER 1849. "Queen Victoria and the royal family, on her return from her late visit in the highlands of Scotland, for the first time made her return journey the whole way by railroad."

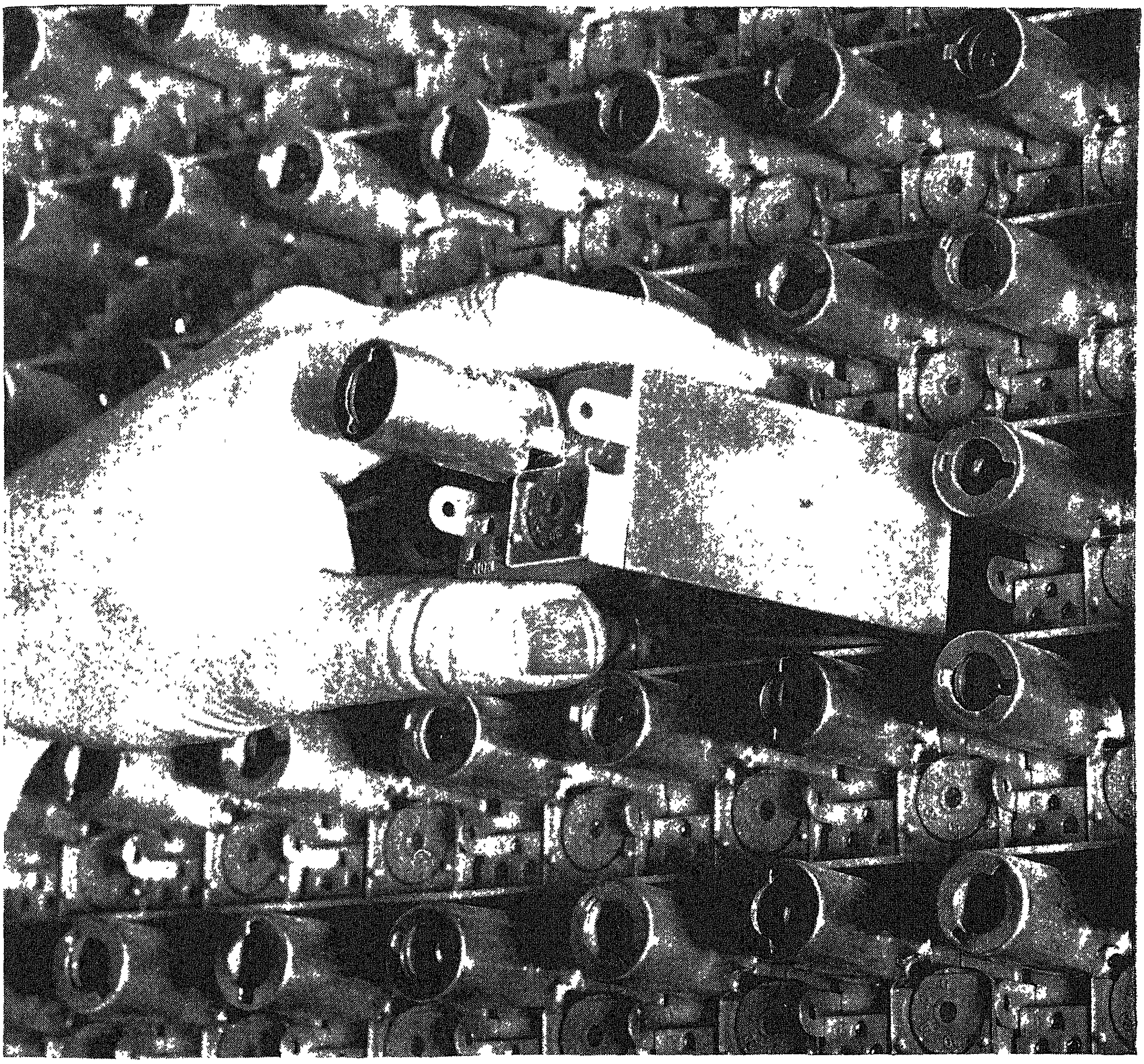
"This is the age of great discoveries in all directions. The railroad has become the magician's rod, the electric telegraph a wire of wonders, and ether and chloroform mysterious alchemies. A tooth can be extracted, a leg cut off, or an incision made into the most sensitive parts, and the patient at the close ask if the operation has begun. Speeches uttered at ten o'clock at night are printed while we are asleep, and they appear in beautiful type upon our breakfast tables at eight o'clock in the morning. The rapidity with which change follows change is also remarkable. Things that took a century to do some time ago, are now finished off in the course of a day."

"An iron steamboat is now building in this city to run on Lake Titicaca, which lies in the bosom of the Andes, in Peru, five miles above the level of the sea. It is to be made in sections, to be transported from the sea on the backs of mules, to its lofty native element, and there it is to be put together by mechanics sent out for that purpose."

"Some ingenious experiments have been performed at the Cincinnati Observatory, in connection with the magnetic telegraph, to ascertain if there be any sensible time occupied in the transmission of the wave or current of electricity between the two points where relative longitudes are required. Thus far, Professor Mitchell says, all results tend to the conclusion that there is no sensible wave time. Other methods may lead to a different conclusion. The subject is interesting, and now becomes important as an element in the determination of longitudes by the telegraph."

"Patent issued to John Ericsson, of New York, for improved arrangement of engines for using steam expansively."

"The experiments of Leblanc upon vitiated atmosphere are of high interest. The quantity of carbonic acid in the atmosphere in the normal state, has been shown by the Saussures to vary from 3 to 6 parts in 10,000. Leblanc has examined the quantity in crowded rooms, theatres, cities, &c. In Dumas' class room, after a lecture of an hour and a half, where 900 persons were present, the carbonic acid amounted to 1 per cent, and the same quantity of oxygen had disappeared. From other experiments, he considers this a maximum quantity for safety, and strongly recommends a better ventilation when so much carbonic acid is present. The result agrees with experiments made in this country."



THE COVER

The glass porthole in the center of this month's cover painting gives a view of the inside of a shock tube, a device used in the study of shock waves at the University of Michigan's Harrison M Randall Laboratory of Physics (*see page 14*). The steel tube itself, which extends beyond the picture on both sides, consists of two chambers separated by a red cellophane diaphragm. To establish a pressure difference, the air in one chamber is compressed or the other chamber is evacuated When the diaphragm is ruptured, a shock wave travels down the tube. Because the optical properties of air vary with its density, this wave can be seen and photographed through the porthole. In the painting a double-wedge airfoil is mounted inside the porthole. The turbulence caused by the passing shock wave is clearly discernible. Specks of red cellophane have been carried down the tube by the shock wave Reflected in the glass of the porthole is the head of a watching physicist. To the lower left are a plateholder and a package of photographic plates.

THE ILLUSTRATIONS

Cover by Stanley Meltzoff

Page	Source
12	Irving Geis
15	Ballistic Research Laboratories, Aberdeen Proving Ground
16-17	Eric Mose
18-19	Harrison M. Randall Laboratory of Physics, University of Michigan
20-24	David Stone Martin
32-39	Mount Wilson and Palomar Observatories
41-43	William Auerbach-Levy
44-45	Adolph Brotman
47	Jack Manning
48	The New York Public Library
50	Geoffrey W. Rake, The Squibb Institute for Medical Research, and Harvey Blank, Lewis L Coriell and T. F. McNair Scott, The Children's Hospital of Philadelphia
52-55	Adolph Brotman
61-63	John F. Gregory

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CONTENTS FOR NOVEMBER 1949 VOLUME 181, NUMBER 5

ARTICLES

DEPARTMENTS

SCIENTIFIC AMERICAN

NOVEMBER 1949 VOL. 181, NO. 5

Arms Race v. Control

Does the atomic explosion in Russia require the U.S. to modify its position in regard to the international control of atomic energy?

Not many events in recorded history have been so cataclysmic as to force a sudden change in the thinking of mankind. Newton's laws of motion, the steam engine, gunpowder—even these revolutionary discoveries were centuries in developing their full impact upon human affairs. How different is the case in the fifth decade of the 20th century! Four years and 69 days after the explosion of the first atomic bomb the world heard the dreaded echo that brought it face to face with a most fateful decision

The Russian atomic explosion means that the world race in atomic arms has begun The practical and immediate decision that confronts mankind is whether to let the race get irrevocably started on its predictable course or to make a real and determined attempt to establish international control of atomic weapons The first response of most U. S. officials to the Russian explosion was to declare that the U S. must maintain its lead and increase its production of atomic bombs There may be some who hope that this will be permanent U. S. policy, but thoughtful Americans and the peoples of other nations must certainly hope that these statements simply mean that the U. S intends to preserve a strong bargaining position until an agreement on international control can be reached

What are the chances of obtaining such an agreement? The record of the United Nations Atomic Energy Commission's discussions during the past three years has been discouraging. But the deadlock has been due at least in some part to a stiff adherence by the principal powers to their respective "plans." Now, as such eminent commentators as Walter Lippmann have observed, the end of the U S monopoly fundamentally changes the premises of the negotiations. It makes it possible to wipe the slate clean and retire gracefully from commitments to details of the official plans. To relieve mankind's anxiety over the menace of atomic war, what seems to be called for is not a gilt-edged plan but an agreement

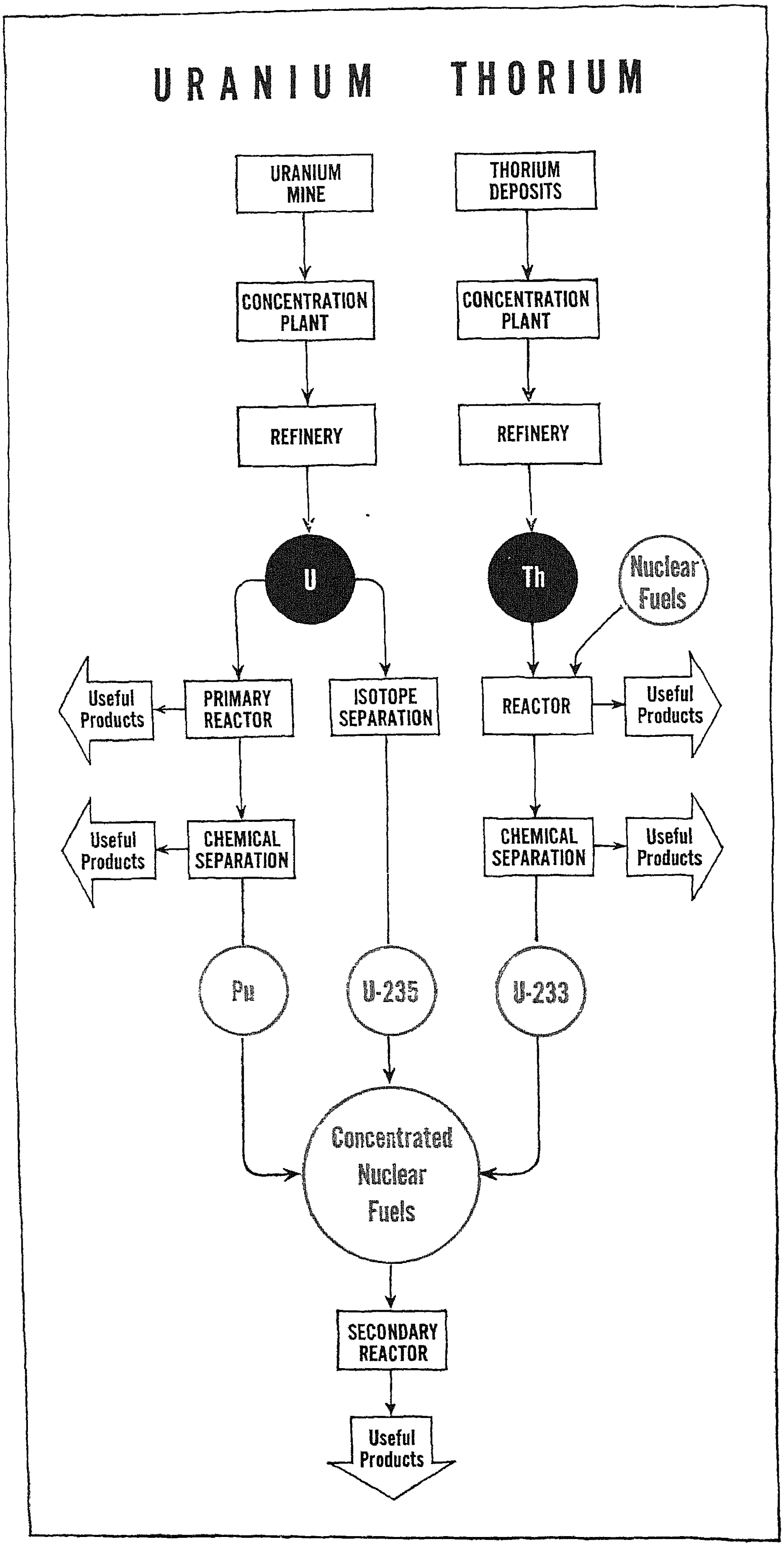
The problem of the control of atomic energy is the most urgent, the most desperate, ever faced by the American people, or indeed by mankind in its whole troubled history. It is a problem that demands leadership from scientists and from all who can bring an informed intelligence to bear upon it In the following article the problem is discussed realistically by a member of the board of consultants which in 1946 prepared the so-called Acheson-Lilienthal report, the first formal proposal and specific program for the international control of atomic energy

by Chester I. Barnard

WHEN President Truman announced that an atomic explosion was known to have occurred somewhere in the area of Soviet dominion, my immediate reaction was that the chances of attaining the international control of atomic energy under the aegis of the United Nations had increased rather than decreased. It is in many ways an advantageous thing that parties looking to an agreement should enter the discussion without either one being at too great a disadvantage. One man with a gun finds it hard not to assume a superiority which hampers negotiation. Two men with guns are not necessarily going to shoot it out. Thus, though the use of atomic weapons is now more dangerously imminent than before, the dilemma of the United Nations is less acute and the possibilities of successful negotiation are measurably improved.

In 1946 the State Department board of which David E. Lilienthal was chairman and I was a member arrived quickly at agreement on a general plan for the international control of atomic energy. Yet it seemed to me at the time that, logical and sound as the plan was, the chances of its adoption were very small. This estimate was not by any means based exclusively on the possibility of determined opposition to the plan by the Soviet Union. It appeared likely that every country, including our own, would encounter extreme technical and popular difficulties in renouncing that considerable portion of its national sovereignty which acceptance of the contemplated pact would require. The fact that substantially the plan proposed by our board finally proved acceptable to all members of the United Nations Atomic Energy Commission except the Soviet Union and its immediate satellites was heartening It must be remembered, however, that approval of the plan by representatives of these nations in the United Nations Atomic Energy Commission is by no means the same thing as the final and formal approval required for the execution of the necessary multilateral treaties to carry the plan into effect.

It was also obvious from the outset that so long as one of the negotiators possessed a preponderance of knowledge of atomic energy science and technology,



PROCESSES required to obtain power and other useful products from uranium and thorium outline the problem of control. Uranium yields two nuclear fuels: U-235 and plutonium. Thorium yields U-233. Under the Acheson-Lilienthal plan individual nations could use "denatured" fuels, but an Atomic Development Authority would control stages of their manufacture.

as well as an actual monopoly of production resources and of fissionable materials, the chances of agreement could not be high, for the parties lacked the equality of status that makes for success in bargaining. The position of the U S involved one of the most extraordinary dilemmas in history. Though our plan embodied the most generous ultimate intentions of relinquishing our preferred position, actual possession of the bomb could be given up only in consideration of comprehensive and genuine guarantees that, in the end, all nations would forego the use of weapons employing atomic energy. This inevitably meant that other nations would have to relinquish, step by step and voluntarily, important elements of sovereignty in advance of the relinquishment of the bomb by the U. S. It is hard to imagine conditions less favorable to successful negotiation by proud and equal nations. And the difficulty was not reduced by the exaggerated importance that our temporary monopoly of atomic energy knowledge assumed in the minds of the American people

Now that the Soviet Union apparently also has the bomb, there will have to be some changes in our tactics and our attitude. It has always seemed to me a most dangerous delusion to suppose that our preferred position in the field of knowledge and technology could last very long or that our superiority with respect to the stock of fissionable materials could be maintained indefinitely It is surely no great surprise that the essential knowledge is held by several, if not by many, nations and that in fact an atomic explosion has now occurred under other auspices than our own. The status of the participants in the attempt to negotiate an international agreement has become less unequal and with the lapse of time presumably will become progressively more nearly equal.

It would be a mistake to focus all attention on the atomic bomb to the exclusion of the other terrible modern weapons of warfare When a British commentator observed wryly that "the Russians have devalued the bomb," his remark was true in more than one sense, it was more than the mere devaluation of a monopoly. Once the atomic bomb becomes an international weapon, so that it confers no overriding advantage upon its possessors, the result must be to increase the pressure upon all nations in any universal arms race to develop even more effective weapons of mass destruction. Already, in the short period since the end of the war, this effort has got under way. Guided missiles and rocket bombs, chemical and biological means of warfare are presumably being advanced every day, not by a few nations but by many nations. Dangerous biologicals could be made in small laboratories

in small countries. Chemical poisons could be produced and assembled anywhere. And it must be remembered, after all, that the squadrons of B-29 bombers carrying conventional explosives and fire bombs produced more casualties in Tokyo in one night than the two atomic bombs on separate days in Hiroshima and Nagasaki. For the present, swift improvements in all these weapons are as likely as epoch-making changes in the atomic bomb or other destructive uses of atomic energy.

Thus the control of atomic energy is only a part of the much larger problem of the control of war itself. But in many symbolic and practical ways it occupies perhaps a decisive position in the larger problem. The atomic bomb so far is unmatched as a means of surprise attack. Aside from general dispersal of the population and industry, little or no defense against it seems in prospect. Moreover, from the military point of view it is a remarkably economical weapon, at $1 million per bomb it is a far cheaper method of destruction than its equivalent in chemical explosives and the extra planes to carry them.

At the same time, in certain respects the control of the atomic bomb might not be as difficult as that of other modes of warfare. Its spectacular character makes it not too hopeless to expect that we may arrive eventually at some sort of an agreement on the curbing of this one most vivid form of warfare.

What makes the atomic bomb unique is that, as recent statements by naval officers in Washington have reminded us, this is the first weapon primarily directed to the indiscriminate annihilation of civilian populations. As such it introduces an entirely new concept of warfare. To be sure, the concept of total destruction has long been discussed by theoreticians and was put into practice to some extent in the last war, but now that the atomic bomb has made it practically realizable, this concept must inevitably dominate all military strategy—unless the bomb is placed beyond the pale So the curbing of atomic weapons would go a long way toward controlling the menace of annihilative war, including bacteriological warfare and all the rest.

The stakes are enormously high. In my opinion, they involve not only peace but also whether we shall be forced to have a totalitarian government. If dispersal of the population is the only immediate means of reducing vulnerability that we can hope for, then we should have to carry the control of private lives to unheard-of lengths in this country. We should recall that governments in the past have always found that the hardest thing for any central authority to undertake is the deliberate shifting of a population against its wishes. The defense measures that would be absolutely necessary in the event of a protracted failure to get international agreement would mean an intolerable central management of our lives. Such control has already progressed to the point where it threatens the freedom of science.

The principal issues in the international control of atomic energy that have been under discussion in the UN can be stated succinctly in a series of questions Shall an international authority take ownership of the raw materials (uranium and thorium) and operate all potentially dangerous projects in atomic energy, or shall each nation develop its own atomic energy program, with international inspectors to see that it does not make atomic weapons? Shall atomic disarmament proceed in a series of stages, or shall atomic bombs be outlawed and existing stockpiles be destroyed by immediate agreement? Shall charges and penalties against a nation accused of violating the control agreement ultimately be decided by a majority or by a unanimous vote of the UN Security Council?

Obviously the present new situation reduces the significance of some of the points that have been strenuously debated in the past, notably the question of stages. It seems safe to say that too much has been made of the veto question, especially in the beginning. Time has passed and there has been less debate about the veto, for one thing because there was no great clarity on just which form of veto people were talking about. The entire veto problem has no cogent connection, so far as I can see, with the central question at issue. Of course it offends our sense of the proprieties to be told that anyone accused of committing a crime should be able to veto an inquiry into the facts. But if some nation violates an international agreement, others are not going to wait the months and months which may be required for the Security Council to complete a thorough investigation. If under these conditions a violation should occur, to all intents and purposes war would already have been declared. The veto would then be irrelevant, all rules would be off. Under the United Nations Charter all nations can, in certain circumstances, defend themselves. The violation of an international atomic energy agreement would certainly be such a circumstance.

ALTHOUGH international atomic energy control is not equivalent to the abolition of war, it is a step in that direction. It is a step that should be taken, and a step from which no quibbling, not even quibbling of the more serious sort, or any hurt feelings, should deter us. In the years since the close of the war some of our neighbors have begun to develop inferiority complexes, and America more than once has shown evidences of a high-hat complex We have not been quite aware of how difficult it is for others not to become oversensitive, and how easy it is for us to offend.

Perhaps the major reason why the discussions of atomic energy control have heretofore been doomed to reach a stalemate is that out of sheer pride not every big power has been willing to give up its efforts to develop atomic energy. The Soviet Union now feels itself in a happier position. At the same time, although we have become more vulnerable, the Soviet Union is not less vulnerable than before. Although each nation now possesses the crucial weapon of attack, it has less direct incentive to use it—since it is an axiom of warfare that attack calls for retaliation. Even if we were to assume that we were certain to win a war because we could use the atomic bomb on a larger scale than anybody else, would such a victory be worth taking? Could any nation, however greedy, rejoice or even benefit from possession of a land in which all the works of civilization had been destroyed?

With two large and rival nations in possession of deadly atomic weapons, the peace of the world is grimly endangered, especially since tensions have been developing apace and there has thus far been no progress on an international agreement. But if we look back to various junctures in our own history and note how dark things must have looked to those who were then facing an unknown future, we should take heart. After reading about our nation's past crises in our history books, even today we do not see how it could have worked out its destiny—but it did Concrete reality is easier to face than remote possibilities. At least we are now confronting a concrete situation. And what is even better, discussions have now been resumed.

In our panic over the destructive potentialities of atomic energy we have been inclined to lose sight of its potentialities for progress So far we have had only glimpses of what atomic energy can do for mankind—as a source of power, as an aid to medicine, as a tool for basic research. Before these more hopeful aspects of atomic energy can receive our undivided attention, it is necessary to remove the clouds of apprehension now more than ever darkening the international sky. No one can or should be too sanguine about the ease of the task—or wait too passively for something to happen. It is always a good thing not to assume too early that a situation is entirely hopeless Here we can say literally that while there is life there is hope Four or five years ago the chance of achieving successful international control seemed to me about one in 100. Now it is perhaps one in 50, and it may get better as time goes on.

Chester I. Barnard is president of The Rockefeller Foundation.

SHOCK WAVES

The phenomenon is observed when gases are violently disturbed by explosions, missiles or machines. It is studied for both practical and theoretical reasons

by Otto Laporte

OUR accelerating civilization must increasingly reckon with the phenomenon of the shock wave Wherever compressible gases move—in explosions, past missiles, through jets or turbines—shock waves play a significant role. The observation of shock waves is of vital interest to the physicist, the astronomer and the engineer. The theory of shock waves is fascinating to the mathematician.

A shock wave is to a sound wave what a tidal wave is to a ripple in a still pool. This statement is not really a definition, but it will explain why in examining shock waves we must consider what we mean by a sound wave. When a tuning fork is struck or a magazine falls from a table to the floor, small pressure or density disturbances are set up in the air, and the disturbances radiate from the source with the speed of sound. Compared with the normal pressure of undisturbed air, the pressure increase in such a sound wave is very small indeed, in the sounds of our daily experience the increment is only a hundredth to a thousandth of the original air pressure. While propagating the disturbance the air particles leave their positions temporarily, but each individual particle is displaced only a tiny distance, and it moves with only a hundredth or a thousandth of the speed of the sound wave itself.

Since the temperature of air rises when it is compressed and falls when it expands (as is illustrated by the heating of a tire pump or the cooling of a carbon dioxide cartridge making charged water), sound involves a delicate temperature change. The increase of temperature is proportional to, but much less than, the increase of pressure. All these infinitesimal pressure, density and temperature disturbances are propagated through space with the speed of sound. It is well known that the speed of sound varies with altitude, but contrary to a common impression this has little to do with variations in atmospheric pressure; the speed depends only on the temperature of the air. It is also largely independent of the pitch or loudness of the sound. The speed of sound is 1,087 feet per second at 32 degrees Fahrenheit, and it increases as the square root of the temperature measured from absolute zero.

In the case of shock waves we are dealing with pressure changes much larger than those of ordinary sound; in fact, the pressure increase may be greater than the total original atmospheric pressure Such shocks, though not encountered as frequently as ordinary sounds, are common enough. The noise of a tire blowout, the blast of an explosion—whether it be a bomb or the volcano Krakatoa—are examples of pressures higher than atmospheric that are released suddenly. Conversely, the report we hear when an evacuated container such as a carbon filament lamp or a Thermos bottle breaks is the result of a sudden pressure reduction. The former are examples of compression waves, the latter of rarefaction waves. The term wave is used here to describe a disturbance of pressure, but not necessarily a periodic one. The periodic character of the small changes of pressure in a sound wave propagating a musical note is not really essential to the phenomenon. (The large effect of the trumpets of Jericho should probably not be regarded as proof of the magnitude of the pressure changes, more likely it should be ascribed to resonance)

The propagation of these large disturbances is quite different from that of small sonic disturbances. The latter always have a definite speed—the speed of sound in everyday experience. The speed of a large disturbance, or shock wave, varies with the amount of the pressure change. the greater the pressure increase, the faster it travels. This is due to the temperature effect mentioned earlier.

THE origin and development of a shock wave are depicted in the drawings on page 16. The top drawing shows three regions of differing air pressure. The air in the region at the extreme right is at rest; its pressure is p_0. To the left of it is a region of higher pressure, p_1, and at the far left one of still higher pressure, p_2. Obviously this situation will result in air movements of a certain pattern and velocity. If the p_0 region is at rest, the entire air layer of the p_1 region will rush to the right with a certain velocity which is constant for the whole plateau The p_2 air layer also will rush to the right, in other words, it moves faster than the p_1 layer, its speed in relation to the p_1 layer being approximately as great as that of the p_1 layer in relation to p_0 It is therefore clear that the speed of the point B, at the edge of the p_2 region, is much greater with respect to the quiet air in p_0 than the speed of the point A. Hence the compression at B catches up with the compression at A and ultimately amalgamates with it.

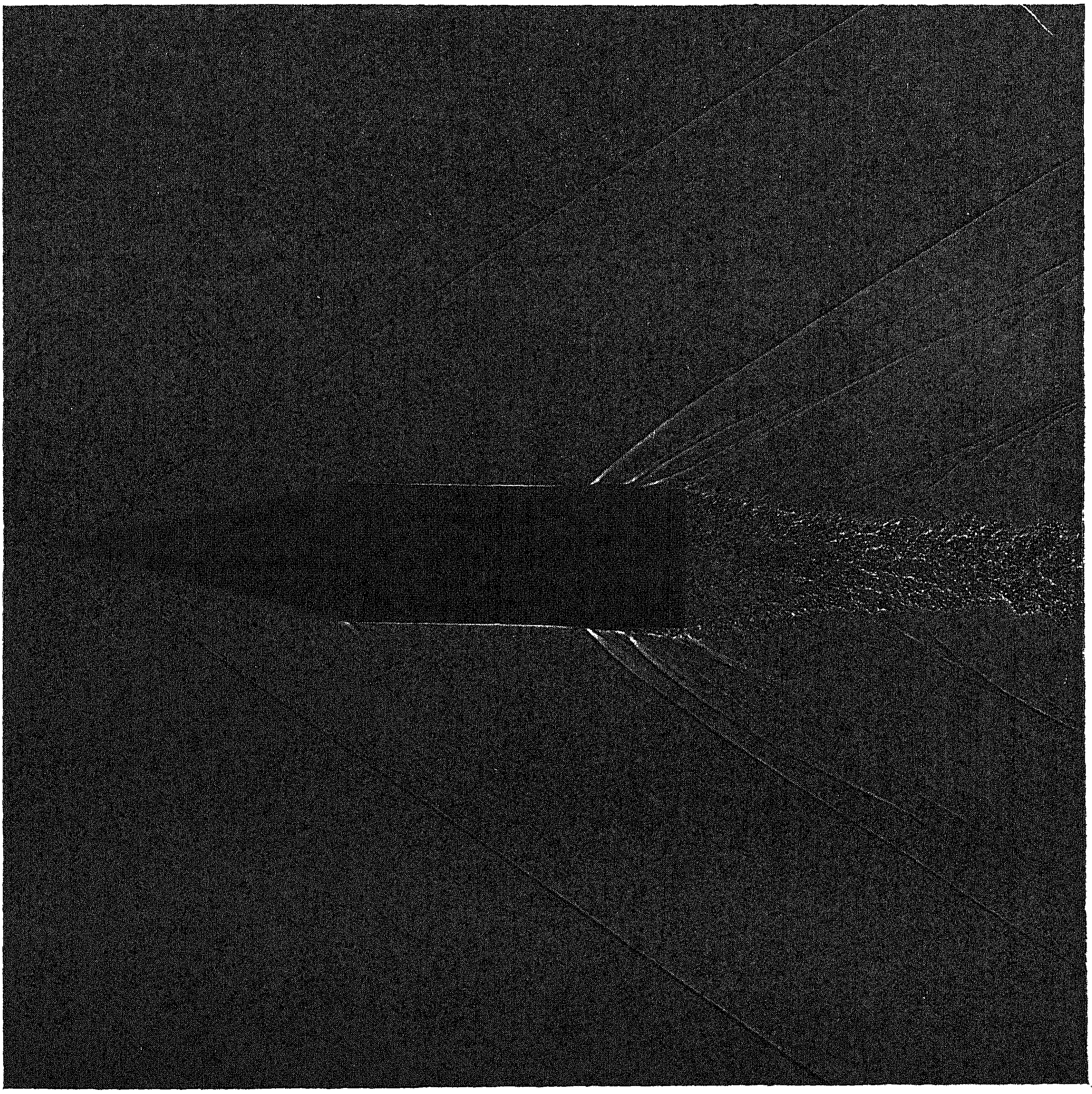
Although we have found it convenient to speak here of just two pressure changes, affecting whole regions, actually the same phenomenon takes place at each point within a single region of compression. This is illustrated in the middle drawing on page 16. There the progress of a single compression wave is shown at very short time intervals. The speed of propagation is *slowest* at A, the foot of the compression, and highest at B, the head of the compression. B starts behind A, but finally catches up with it. This is the genesis of a shock wave. The harmless compression wave traveling to the right steepens more and more until it becomes a sharp discontinuity in pressure, which from then on moves without change into the low-pressure region at the right The effects of this discontinuity are violent because the air particles are enormously accelerated as they are engulfed.

In these two drawings we have, as is customary, plotted pressure as a vertical coordinate against distance. It is a remarkable fact that there is more reality in this way of presenting pressure distributions in compressible gases than might be expected For many years it has been known that there is an exact analogy between the propagation of large pressure changes in compressible gases and the propagation of relatively large waves in shallow bodies of water. The height of the water wave, for example, corresponds to the gas density, and

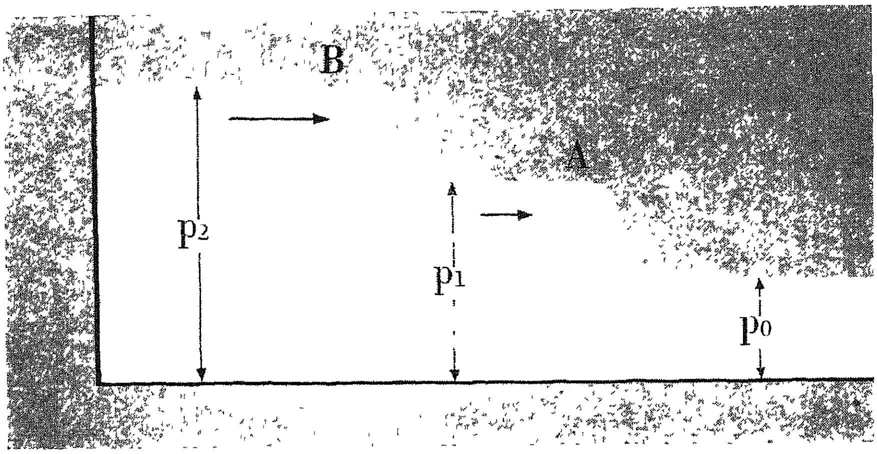
the horizontal components of the water velocity at the surface correspond to the gas velocity. Thus our two drawings take on a more easily visualized character the curves with which the varying pressures were plotted against distance can be regarded as graphs of the height of the water in a shallow tank. In the first drawing two rises in water level are rushing into the quiet water at the right. In the second drawing a plateau of high water is rushing into a region of quiet water. Connecting the two water levels in this drawing is a transition zone in which the speed of the water rises from zero to its final maximum This causes the gradual steepening of the transition zone until a real discontinuity in level, the analogue of a shock wave, is established.

Three different names have been given to this phenomenon in nature. In the ocean such a sharp level discontinuity, which may be caused by a submarine volcanic eruption, is called a tidal wave In very swift mountain streams there are stationary level discontinuities, produced by obstructions or changes in the slope of the stream bed, that slow the stream down, such a discontinuity is known as a hydraulic jump In the mouths of certain rivers the incoming tide steepens into a dangerous discontinuity called a bore Bores have been observed in Canada's Bay of Fundy and in many tropical rivers. Somerset Maugham's famous short story "The Yellow Streak" describes the terrors of being caught by a bore on a river in Borneo

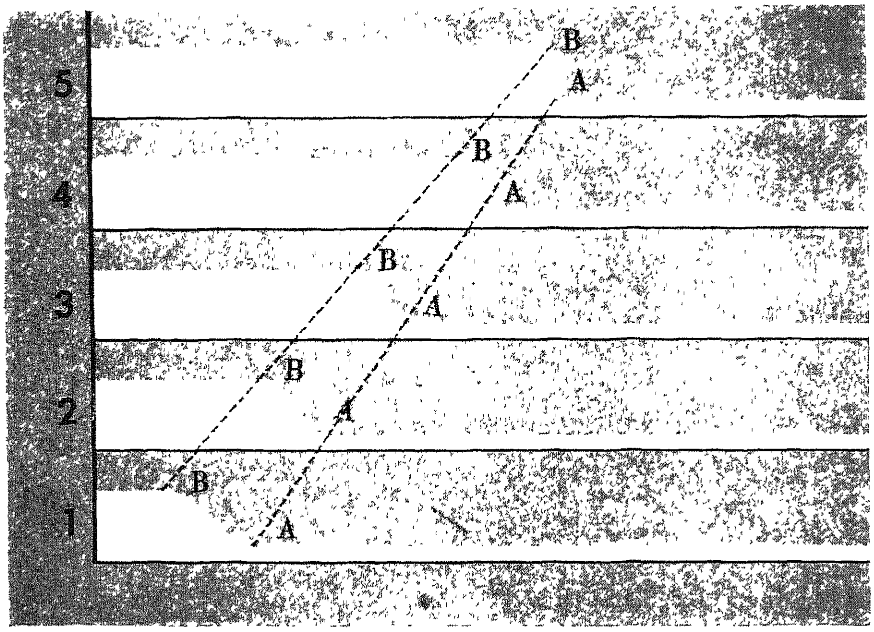
The aerodynamicist is interested in such matters because, as a result of this analogy between the flow of water and of gases, the study of water flow in a shallow tank provides him with a laboratory model of the complicated behavior of shock waves in gases. It is possible, however, to investigate shock waves more directly. This is due principally to the work of the Austrian theoretical physicist and philosopher Ernst Mach, who at the turn of the century



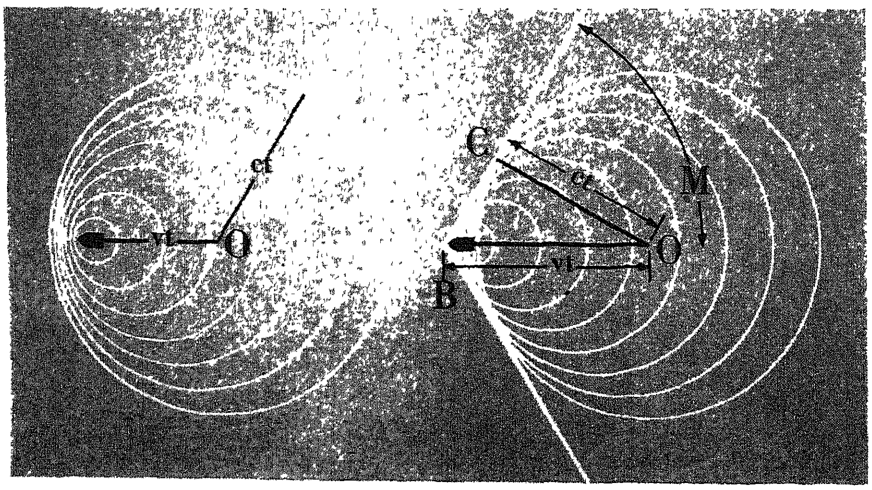
SHOCK WAVES are made visible in a shadow photograph taken at the Ballistic Research Laboratories of Aberdeen Proving Ground at Aberdeen, Md. Here a projectile moves through a gas from right to left. The angle of the shock wave originating at the conical tip indicates that the Mach number of the projectile is 1.88.



CAUSE of a shock wave is demonstrated by assuming a region of low pressure (p_0), a region of higher pressure (p_1) and a region of still higher pressure (p_2). Point B moves faster than A and ultimately catches up with it.



EFFECT of the phenomenon outlined in the drawing at the top of this page is to cause a harmless discontinuity in pressure (1) to become sharper (2, 3 and 4) until it is the violent discontinuity of a shock wave.



BULLET moving through the air at a speed less than that of sound (*left*) is surrounded by a succession of spherical waves. When the bullet moves faster than sound (*right*) the disturbance forms conical shock wave pattern.

developed methods for observing actual shock waves in air.

There is a phenomenon, akin to a certain effect of shock waves, which is familiar to everyone—the layers of hot air, separated by visible boundaries from the cooler air above, that one can see over a hot radiator beneath an open window or on a hot pavement in summer. The sharp differences in temperature produce sharp differences in the density of the air. A shock wave, similarly, represents a discontinuity in density, and the air on one side of the wave has optical properties different from those of the air on the other. The problem in observing it, of course, is that a shock wave is extremely transient. Shock waves can be photographed only by the use of delicate and ingenious timing devices for tripping the camera.

The most common application of this technique is to photograph the flow of air around objects, notably bullets in flight. The tip of the bullet forms the vertex of a conical shock wave. This is the visible manifestation of a discontinuous change in the velocity of the parted air. The shock waves here are more complex than those pictured in our simplified diagrams—they are curved and oblique. By oblique we mean that the flow velocity is no longer perpendicular to the wave front, it intersects the wave front at an angle. This conical shock or bow wave is typical in supersonics, and by considering it we will arrive at a deeper understanding of the shock wave phenomenon.

LET us look at the bullet first as if it were a small disturbance, like a sound wave. Let us furthermore imagine that we are riding the bullet, Munchausen-fashion, and watching the air rushing by. We may then account for the effect of this small disturbance, as did the 17th-century Dutch natural philosopher Christian Huygens, as a steady succession of spherical waves. It is as if, standing on a bridge above a swift stream, we watched the surface of the stream flow by a point of small disturbance such as might be created by a fishing line hanging in the stream, except that here the disturbance is more like a succession of drops falling upon the surface. As long as the speed of the bullet, corresponding to the speed of the stream, is less than the speed of sound, corresponding to the speed of the circular ripples propagating the disturbance, the effect will be merely a series of circles that are somewhat crowded on the upstream side, or the direction of the bullet's flight, as shown in the drawing at the bottom of this page.

Now let us go on to picture the quite different effects when the bullet travels faster than sound. As soon as it exceeds the speed of sound, a conical envelope of spheres known as the Mach cone is formed; this is shown in the second drawing at the bottom of the page. The

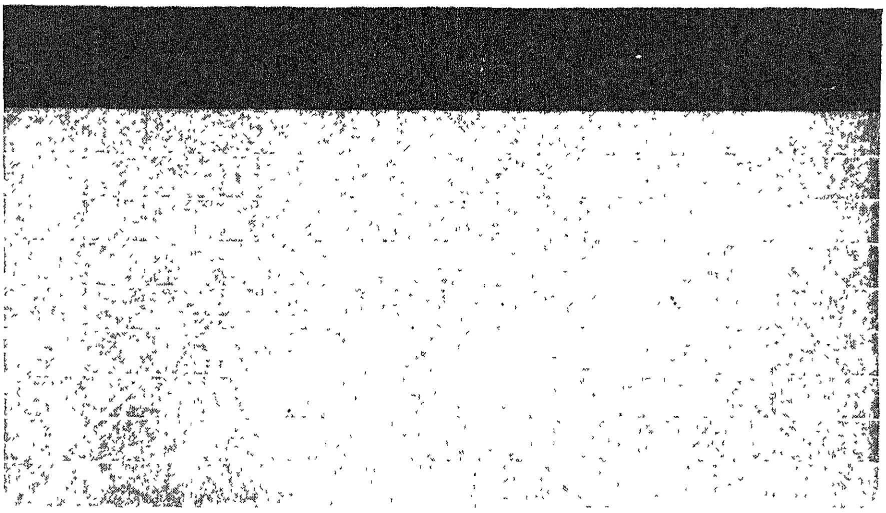
shape of the Mach cone is completely defined by the Mach angle, indicated by M in the drawing. Both the Mach angle and the celebrated Mach number are found by considering the triangle BCO. If the bullet takes t seconds to travel from O to B at a velocity v, then BO is equal to vt. O is the center of a sphere of disturbance that touches the Mach cone at C, and c is the velocity with which the disturbance travels from O to C. Thus OC is equal to ct. The ratio v/c is the Mach number. As long as the Mach number is less than one, which is the case when the bullet is traveling slower than the speed of sound, no Mach cone exists. When the Mach number is one, that is, when the speed of the bullet exactly equals the speed of sound, a Mach cone begins to form. As the speed of the bullet increases and the Mach number exceeds one, the Mach cone becomes more and more slender. For Mach number 2.5, as an example, the Mach angle is only 23 degrees.

The transsonic case, when the Mach number becomes one, is of course a condition of considerable interest to aerodynamicists. Here the Mach cone, with M a right angle, is not actually a cone but a plane perpendicular to the line of flight. We leave it to the reader to identify this plane with the "sonic barrier" so often mentioned in the daily press.

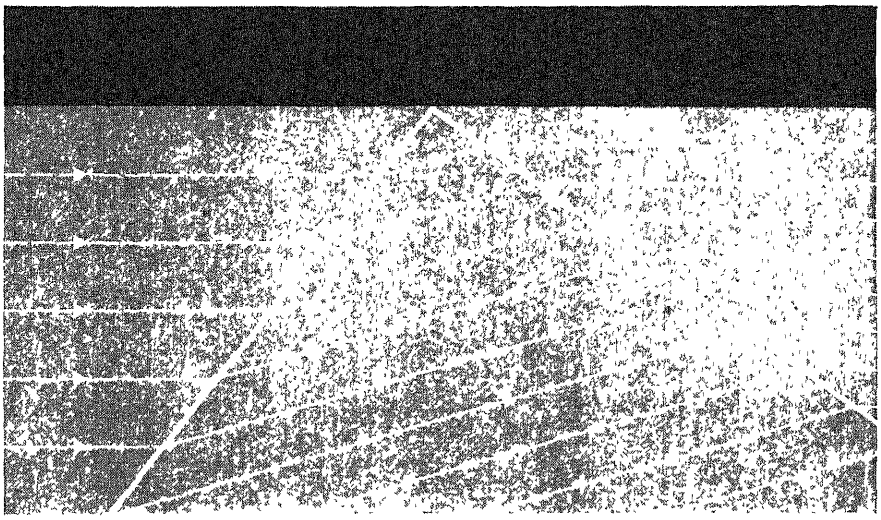
When a bullet or other missile traveling faster than sound strikes an object, part of the damage is due to the conical shock waves which accompany it. This fact has led to the study of how shock waves are reflected from walls. The problem has been thoroughly investigated, and various unexpected phenomena have been discovered. We can simplify the discussion of them by using the term "the strength of the shock," which is defined as the ratio of the pressure before the passage of the shock to the pressure afterward. A shock is strong when the ratio is much greater than one. It is weak, and equivalent to a sound wave, when the pressure changes little.

When a sound wave or a weak shock is reflected from a wall, the angle of reflection is equal to the angle of incidence, as in the case of light. The drawing at the top of this page illustrates this simple situation. If we use the analogy of water once again, we can imagine that we are looking down at a swift stream, flowing in the direction of the parallel lines, with a fishing line penetrating the surface at a point off to the lower left. When a ripple from this point strikes the shore, it is reflected back into the stream at an angle equal to that at which it strikes.

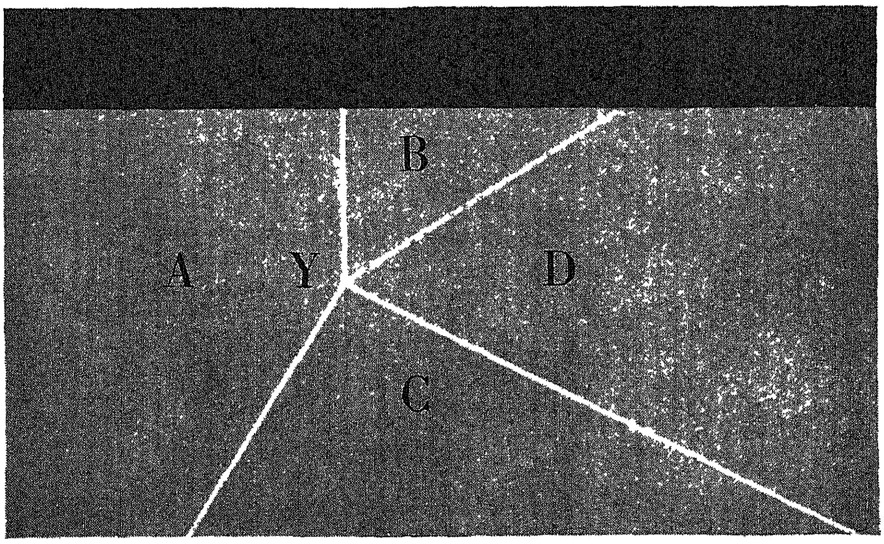
The drawing at the middle of this page illustrates the situation when the weak sonic disturbance is replaced by a shock of medium strength. Here the water analogy might be the passing of a speedboat moving to the left. The bow wave



WEAK SHOCK (*heavy white line*) is reflected from a surface (*dark gray area*) at the same angle with which it strikes. The flow of a fluid crossing the boundaries of the shock (*dotted lines*) is not appreciably affected.



STRONGER SHOCK is reflected from a surface at an angle different from the one with which it strikes. The flow of a fluid is sharply bent as it crosses each boundary. Pressure of fluid at right is higher than that at left.



STILL STRONGER SHOCK produces an entirely different pattern of shock waves. Fluid flowing from A passes through two shock waves to enter C and D. Fluid flowing into B is sharply differentiated from that in D.

of the speedboat is represented by the shock at the left. The pattern is now quite asymmetrical; the reflected shock comes from the shore at a smaller angle than the one at which the original shock hit the shore, and the flow of the stream is refracted sharply where it encounters the disturbance. What is of greater practical interest is the dangerous fact that when the stream passes through the original shock its pressure is increased When it passes through the reflected shock, its pressure increases again, but this time the increase is much greater. In other words, the reflection of shock waves raises the pressure to many times the original, and accounts for much of their devastating effect. This type of reflection, irregular though it may seem by comparison with the reflection of light or sound, is called "regular reflection" in modern aerodynamics.

If a still stronger shock is imposed on the fluid, regular reflection becomes impossible and is replaced by an entirely different and more complicated phenomenon. This effect, which has lately come to be called the Mach reflection, is illustrated in the drawing at the bottom of page 17. Here the fluid moving from left to right is divided by the point Y into two sections of differing behavior. The fluid particles arriving above Y will pass through a single shock wave into region B, bounded by the wall and the dotted line The fluid below Y passes through two shock waves, first into region C and then into region D The flow of the fluid in regions B and D is not identical. The flow in region B changes abruptly at the dotted line, which represents a discontinuity similar to a shock but less drastic. Although the pressure is the same on both sides of the dotted line, the speed of flow, temperature and density are different. It should be noted that this pattern does not remain stationary point Y moves away from the wall

WHILE all these phenomena are of interest in themselves, they have a special, practical importance to the aerodynamicist. The aerodynamicist must know the entire distribution of air velocities around an airplane or a missile and the over-all forces such as lift and drag. The best apparatus for studying these phenomena is a supersonic wind tunnel. In it a stream of air of known speed is blown past a stationary object. The velocity distribution, with its shock waves, can then be photographed. Lift and drag can be measured. Unfortunately the power required to drive a stream of air at supersonic speed through a wind tunnel of reasonable size is so enormous that only a few such tunnels have been built. The power requirement can be reduced by evacuating one or more large containers and then letting air rush back into them through the tunnel. The recently dedicated supersonic tunnel of the Naval Research Laboratory at White Oaks, Md., works in this manner.

Fortunately shock waves themselves can be observed by physicists with a much simpler device. This is the shock tube, invented by a Frenchman named Vieille in the last century and developed by W. Payman and W. F. C. Shepherd in England and by W. Bleakney and Lincoln G. Smith in the U. S. The shock tube is merely a steel tube of uniform cross section closed at both ends. A thin plastic diaphragm in the middle of the tube divides it into two chambers A pressure difference is established either by compressing the air on one side of the diaphragm or by partly evacuating the air on the other side. When the diaphragm is punctured, a shock wave travels into the expansion chamber and a rarefaction wave travels into the compression chamber.

The sequence of photographs at the right shows the flow of air around a double-wedge airfoil in our shock tube at the University of Michigan. The wedge is facing a supersonic air stream coming from the left and is inclined at an angle of 17.5 degrees to the stream of flow. The first picture shows the primary shock wave, *i e*, the shock separating the still air at the right from the supersonic stream at the left. Since the shock wave has to terminate perpendicularly on the wedge, the lower end of its upper half bends slightly toward the wedge to form a right angle. The lower half, together with the curved bow wave, has arranged itself in the Mach configuration which we have already seen diagrammed in the drawing at the bottom of page 17. Even the discontinuity represented in that drawing by the dotted line is visible in the photograph. In the second picture, made 30 microseconds after the first, the whole phenomenon has moved downstream. The third and fourth pictures, made 56 and 79 microseconds after the first, show how the lower half of the primary shock wave curls around the rear of the wedge to form a vortex To the aerodynamicist this is visible testimony of the lifting force.

These pictures illustrate the great potentialities of the shock tube in observing and recording supersonic flow patterns. For such observations the tube is a competitor of the wind tunnel, but for the direct measurement of pressure distributions and some other phenomena the wind tunnel remains indispensable. The advantages of the shock tube are its simplicity, its more precise control of pressure, density, temperature and the Mach number, and the fact that it may be used to study shock waves in any gas.

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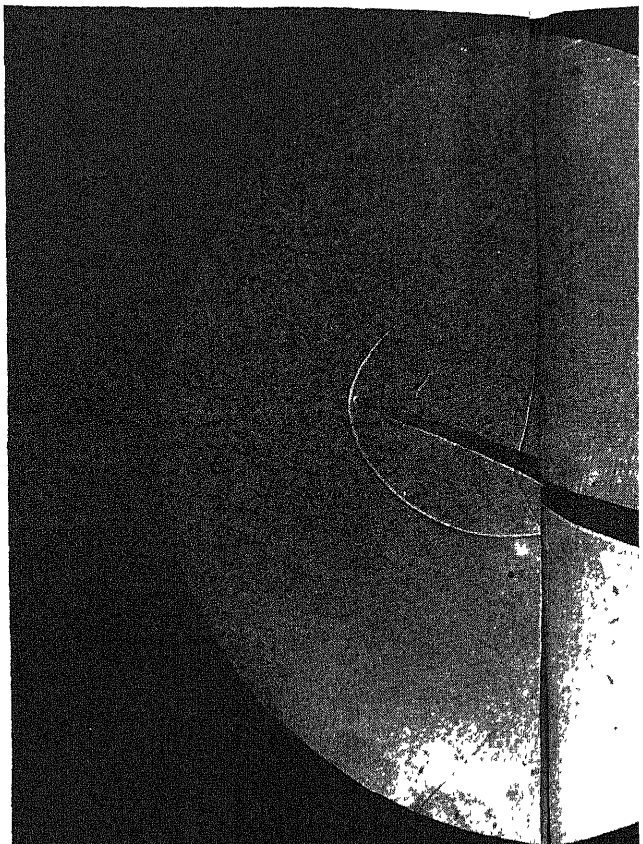
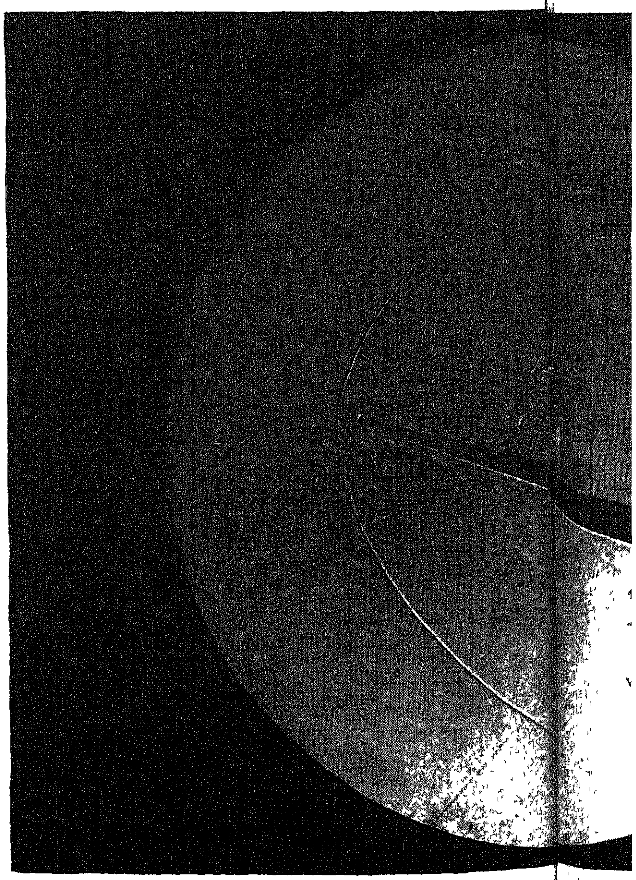
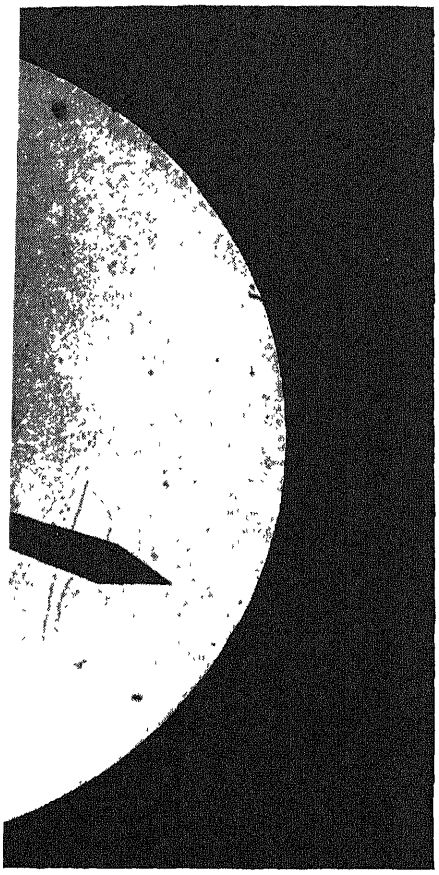


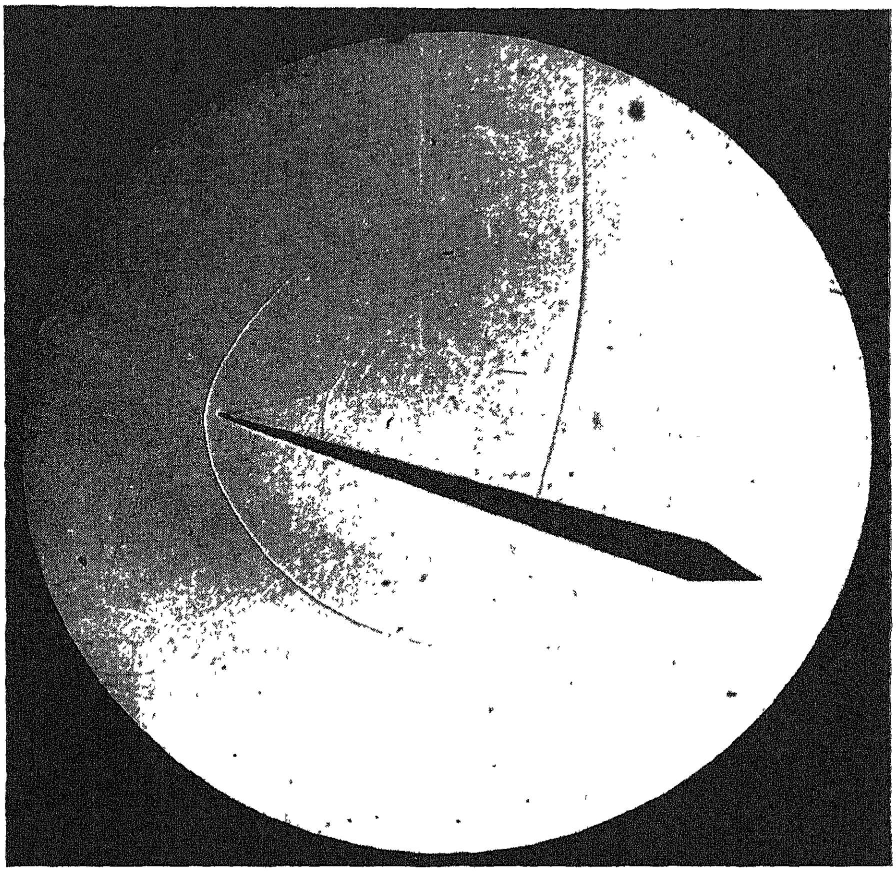
FIRST photograph in a sequence of four shows a wedge-shaped object in



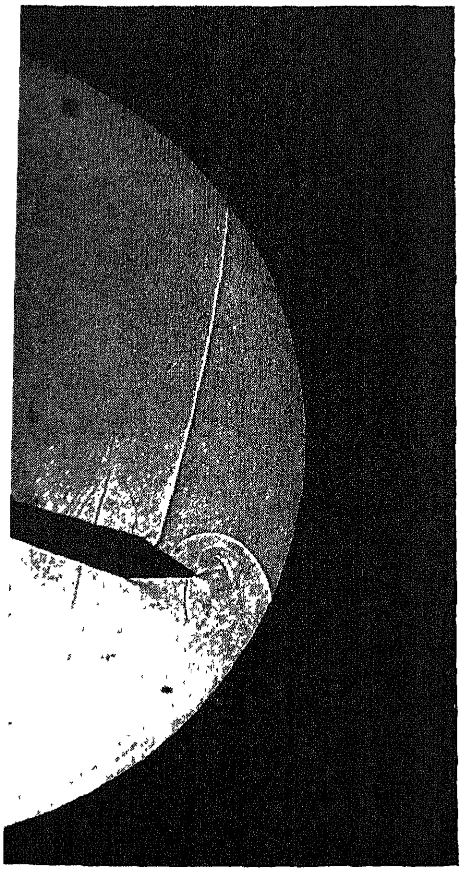
THIRD photograph shows the lower half of the bow wave curling around



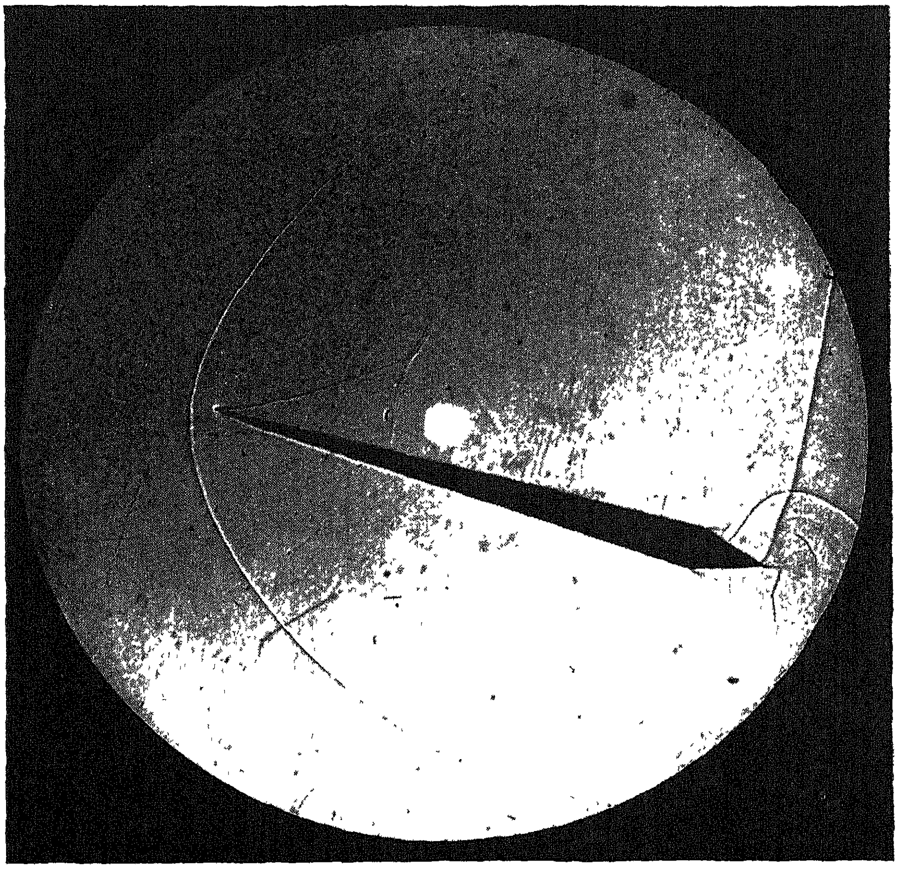
shock tube just after a rapidly moving wave front has encountered it.



SECOND photograph shows the various shock waves moving from left to right with the flow of the gas. Bow wave is at left; Mach reflection at bottom.



the back end of the wedge. This is visible evidence of aerodynamic lift.



FOURTH photograph shows primary shock wave just before it drops off the end of the wedge. Four photographs were made about 30 microseconds apart.

The Ape-Men

During the past 25 years the fossil remains of a whole group of creatures between apes and men have been found in South Africa. A personal account of the discoveries

by Robert Broom

STERKFONTEIN CAVES yielded some of the most significant fossils of the ape-men. This drawing shows Dr. Broom and his assistants at the site where they discovered an almost perfect skull of a female Plesianthropus.

THOUGH there were many eminent evolutionists before Charles Darwin, it was he who in 1859 first convinced the majority of scientists that man had evolved from some ape or apelike being. Of course there were some who were unconvinced, and even today there are still a few, but no scientist of any eminence, so far as I know, would hold now that man is a special creation. Some deny that he evolved by "natural selection" as Darwin suggested, but every scientist probably is satisfied that whether man developed gradually or arose by a sudden mutation, he certainly came from parents who were apes or apelike.

Yet who were his ancestors? That question has preyed on the minds of evolutionists for the last 90 years Among living forms are several which have been claimed as man's nearest lower relatives

The gorilla, the largest living primate, has quite a number of human characters, and some have claimed him as related to man's ancestor. The chimpanzee also has many human resemblances, and possibly the majority of anthropologists today would vote for the chimpanzee as man's nearest relative The orangutan has a few human characters not found in the gorilla or chimpanzee, but it is too specialized to have many supporters. One eminent scientist, convinced that none of the anthropoid apes is close enough to man, has come to the conclusion that he evolved from some unspecialized relative of the monkeylike little Tarsius of Borneo.

The hunt for the fossil relatives of man was for years practically barren of results. The main reason, no doubt, was that very few scientists worried about hunting Most of them found it more comfortable to sit in their professional chairs and do nothing—except criticize the few amateurs who went digging.

In 1889 an ambitious young Dutch doctor, Eugene Dubois of Amsterdam, got himself a post in the Dutch East Indies so he might look for man's ancestors In three years he had found the famous Pithecanthropus skull, which is now acknowledged by all anthropologists to be human. Three other skulls of the same type have since been found.

In 1907 a German scientist, after a deliberate search for some years, discovered a very remarkable human jaw at Heidelberg This represents another type of early man. In 1912 the Piltdown skull, representing still another type, was discovered in the south of England. It has a relatively large brain, and a jaw which in a number of characters resembles that of the anthropoid apes. Then we had the Peking man, a type allied to the Java Pithecanthropus. And finally there is the Rhodesian skull of Africa, another human type.

All these finds were only skulls of various types of early man, and threw little or no light on man's origin. In 1924, however, came a discovery that opened a new chapter in the story of man.

Near Taungs in South Africa is a large lime deposit with a few caves where fossil bones have been preserved. Numerous skulls of small apes or baboons had been found in these caves Toward the end of 1924 a quarryman named M. de Bruyn one day blasted out a small skull which he immediately recognized as that of a being not unlike man. It was believed that he had discovered a fossil Bushman, and the skull was sent to the anatomist Raymond Dart in Johannesburg for his opinion. Dart, after cleaning and studying the skull, promptly sent off a paper to London claiming that it was that of a being intermediate between a higher ape and man. He called it *Australopithecus africanus*.

When the paper appeared, on February 7, 1925, all English and American scientists who expressed an opinion were unanimous in declaring that Dart had made a serious blunder, his little Taungs skull, they held, was only a variety of chimpanzee. Immediately after the discovery was announced I went to Johannesburg to see it and made a very careful examination, especially of the teeth I was at once convinced that Dart was essentially correct in his conclusion, and that this was practically the "missing link"—the most important fossil find ever made. I wrote a paper supporting Dart. The noted paleontologist William J Sollas of Oxford University, to whom I sent a median section of the skull, also was converted to our view, and became our strongest ally

The discussion went on for years, and some of Dart's opponents treated him very unfairly Many in England and America eventually came around to the opinion that he was right, but as the skull was that of a young child, most anthropologists remained unconvinced. The leading American physical anthropologist, Aleš Hrdlička, visited South Africa in 1925 and examined the skull, but did not feel able to give a definite opinion. He said: "Just what relation this fossil form bears, on the one hand, to the human phylum, and on the other to the chimpanzee and gorilla, can only be properly determined after the specimen is well identified, for which are needed additional and adult specimens."

In 1936, having taken a post in the Transvaal Museum in Pretoria at the suggestion of General J. C. Smuts, I resolved to look for a skull of an adult Australopithecus. I felt that even if I did not get what I sought, I was sure at the least to find other interesting fossil forms in the rich cave deposits. I started to work at caves near Pretoria, and immediately found a considerable number of new fossil mammals. Early in August, 1936, two of Dart's students visited me and told me of caves at Sterkfontein, near Krugersdorp, where they had found some small fossil baboon skulls. This seemed so promising a locality that we all visited the cave on Sunday, August 9.

THE caves had been known for over 40 years. Mining operations were being carried on for impure lime in the deposits. G. W Barlow was the manager of the quarrying operations and the caretaker of the caves He told me that he had once worked at Taungs, and that he knew something about the skull. I asked him if he had ever found anything like it at Sterkfontein, and he said he rather thought he had Any nice bones or skulls he found he sold to visitors, and had not worried about what they were. I asked him to keep a sharp lookout for anything like an ape-man skull, and he said he would.

When I visited the caves again three days later, he handed me three small baboon skulls and the badly damaged skull of a saber-toothed tiger. I hunted among the debris and found more of the saber-tooth skull and also a nice canine. The following Monday Barlow handed me two thirds of a beautiful fossil brain cast, and asked, "Is this what you are after?" I replied, "Yes, that's what I am after." It had been blasted out that morning, and it was manifestly the brain cast of a fossil ape-man. I hunted among the blasted debris for some hours, but could get no more of the skull except the cast of the top of it, which I cut out of the side wall of the cave. Next day, after some three more hours' hunting, I found all the base of the skull, both upper jaws, badly displaced, and some fragments of the brain case. When the bones were all cleaned and assembled, we found we had most of the skull, except for the lower jaw, of a creature which we eventually called *Plesianthropus transvaalensis*

During 1936, 1937 and part of 1938 we found many other remains of this Sterkfontein ape-man—bits of skulls, isolated teeth and parts of limb bones. (We now have many skulls and about 130 teeth of Plesianthropus.) We visited the caves every week, sometimes twice a week The native boys were always on the hunt, and I rarely went to Sterkfontein without bringing back some important tooth or bone. Every visit cost some shillings in tips, but it was worth it.

One June day in 1938, when I arrived at the workings, Barlow said, "I have something nice for you this morning," and handed me a beautiful palate of a large ape-man with one molar tooth in position. I said, "Yes, that is a nice specimen I'll give you a couple of pounds for it." He was quite pleased, but did not seem inclined to tell me where he had got the specimen. The matrix was different from that in the Sterkfontein cave, and I was sure it came from some other locality. When I insisted on knowing where it had come from, Barlow told me

a schoolboy named Gert Terblanche had brought it to him from somewhere at Kromdraai, a farm about two miles away.

I went to the farm where Gert lived and found his mother and sister at home The sister took me up to the place on a hill where Gert had broken the skull with a hammer from an outcrop of bone breccia deposit Lying around were a lot of broken fragments of bone and a few teeth. The sister told me that Gert had four teeth with him at school, and she thought he had some pieces of the skull hidden away When I arrived at the country school and with the principal's help found Gert playing outdoors, the boy drew from his trouser pocket four of the most beautiful fossil teeth ever found in the world's history Two of the four fitted on the palate Barlow had given me. The other two had been weathered off. I promptly bought the teeth from Gert and put them in my pocket. Gert told me he had another nice piece hidden away So with the principal's delighted agreement I stayed and lectured to the teachers and pupils on caves and bones until school was dismissed for the day. Then Gert took me up the hill and drew out from his hiding place a very fine jaw with some beautiful teeth.

In the next few days we sifted all the ground in the close neighborhood and recovered nearly every scrap of tooth or bone in the place. When all the bits were cleaned and joined, it was found that we had the greater part of the left side and of the right lower jaw of a very fine skull, with many of the teeth well preserved. The skull differed in a number of characters from that found at Sterkfontein, and it had a larger brain. In some respects it was more human; in a few, less human. We described it as a new genus named *Paranthropus robustus*.

Some English critics considered that I was too daring in identifying two entirely new genera on the basis of skulls which they thought were probably only adult skulls of the Taungs ape. Julian Huxley kindly wrote me suggesting caution. Of course the critics did not know the whole of the facts. When one has jealous opponents it does not seem wise to let them know everything. When later we found the jaw of a baby Paranthropus, we discovered that not only are the Taungs, Sterkfontein and Kromdraai ape-men different genera, they perhaps belong to different subfamilies.

Although work at the caves was almost entirely stopped during the war, we had plenty of material collected to keep us busy. At the beginning of 1946 a book was published giving a full account of all the ape-man remains that had been found up to that date. The book created a considerable sensation in the scientific world. The National Academy of Sciences in Washington has just awarded me the Elliot Medal for it, as the most important work in biology published in 1946.

IN August, 1947, General Smuts phoned to ask me to see him. He recognized that we were discovering the origin of man, and that the work at the caves must be carried on He told me that whatever money I required would be provided by the Government. Alas, as soon as General Smuts had left on a trip to England and America, our Historical Monuments Commission, which believes it has dictatorial rights to decide who is to be allowed to hunt for fossils, and how the work is to be done, intervened and warned me I would not be allowed to excavate except under conditions which I regarded as insulting I was to be allowed to work only in collaboration with a "competent field geologist," who was to be consulted whenever a blast was contemplated. To continue on such terms was impossible, and I had to wait till General Smuts returned from America. When he came back at Christmas he again phoned me. He seemed very angry, and told me to carry on.

I started work at Kromdraai and worked there for three months. Then the Historical Monuments Commission sent me a "permit" to continue work at Kromdraai. Since they did not send me a "permit" to work at Sterkfontein, I immediately stopped work at Kromdraai and started at Sterkfontein without a "permit"

At Sterkfontein we found a crushed palate of a young ape-man and part of the upper jaw of a baby. On April 18, 1948, a lucky blast revealed a perfect skull of an adult female This is the finest fossil skull ever discovered—more important than the Pithecanthropus skull of Java, the jaw of Heidelberg man or the skulls of Peking man. Those were all remains of early man. This was the skull of a being not yet man but nearly man. The skull is practically human in all respects, except that the brain is small—only 480 cubic centimeters.

Of course the discovery was much too important to please the Historical Monuments Commission, especially as it had been made by defying them and by breaking the law. They sent a deputation to General Smuts protesting that in my excavations I paid no attention to stratigraphy and was destroying valuable historical evidence required for dating the specimens. Though there was no truth in the allegation, I was temporarily stopped. However, B. V. Lombaard, professor of geology at Pretoria University, was invited to look into the matter and reported that there was no stratigraphy whatever where I had been working, and that I was doing no harm. So they had to allow me to continue, though still under absurd conditions to which I pay no attention

Our next discovery was an almost perfect male jaw, the most notable feature of which is that though the canine tooth is larger than in man it has been ground down in line with the other teeth exactly as in man. This never happens in males of the anthropoid apes. Then we made an even more important find—a nearly perfect pelvis. This structure, human in all essentials, proves that the ape-men walked on their hind legs.

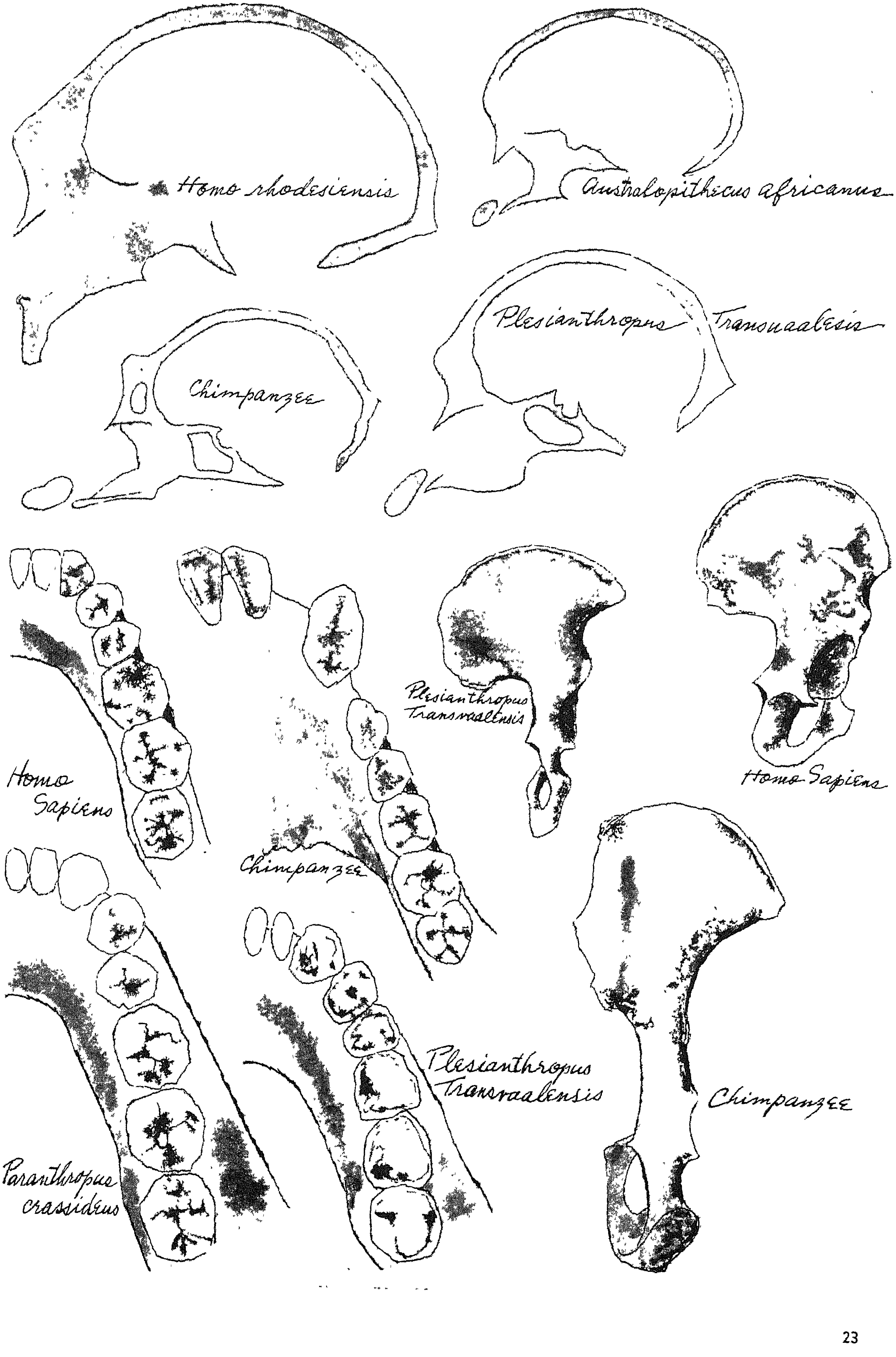
In October, 1948, Wendell Phillips of the University of California Expedition suggested that I might start work at a new cave deposit, he would finance the work and we could share the results. It seemed to me a good plan Hundreds of caves are awaiting exploration. We started at a promising deposit at Swartkrans, only a mile from the main Sterkfontein cave. Immediately we were amazingly successful. Within a few days we discovered a lower jaw of a new type of ape-man much larger than any we had known before. I named it *Paranthropus crassidens*.

While I was visiting the U. S. last March and April, my assistant, J. T. Robinson, discovered at Swartkrans a beautiful, nearly perfect lower jaw. It is really huge, possibly larger than the giant jaw from Java that has been called Meganthropus by the Dutch anthropologist G. H R. von Koenigswald. It almost seems to confirm the view of the noted anthropologist Franz Weidenreich that "there were giants in the earth in those days," as stated in Genesis.

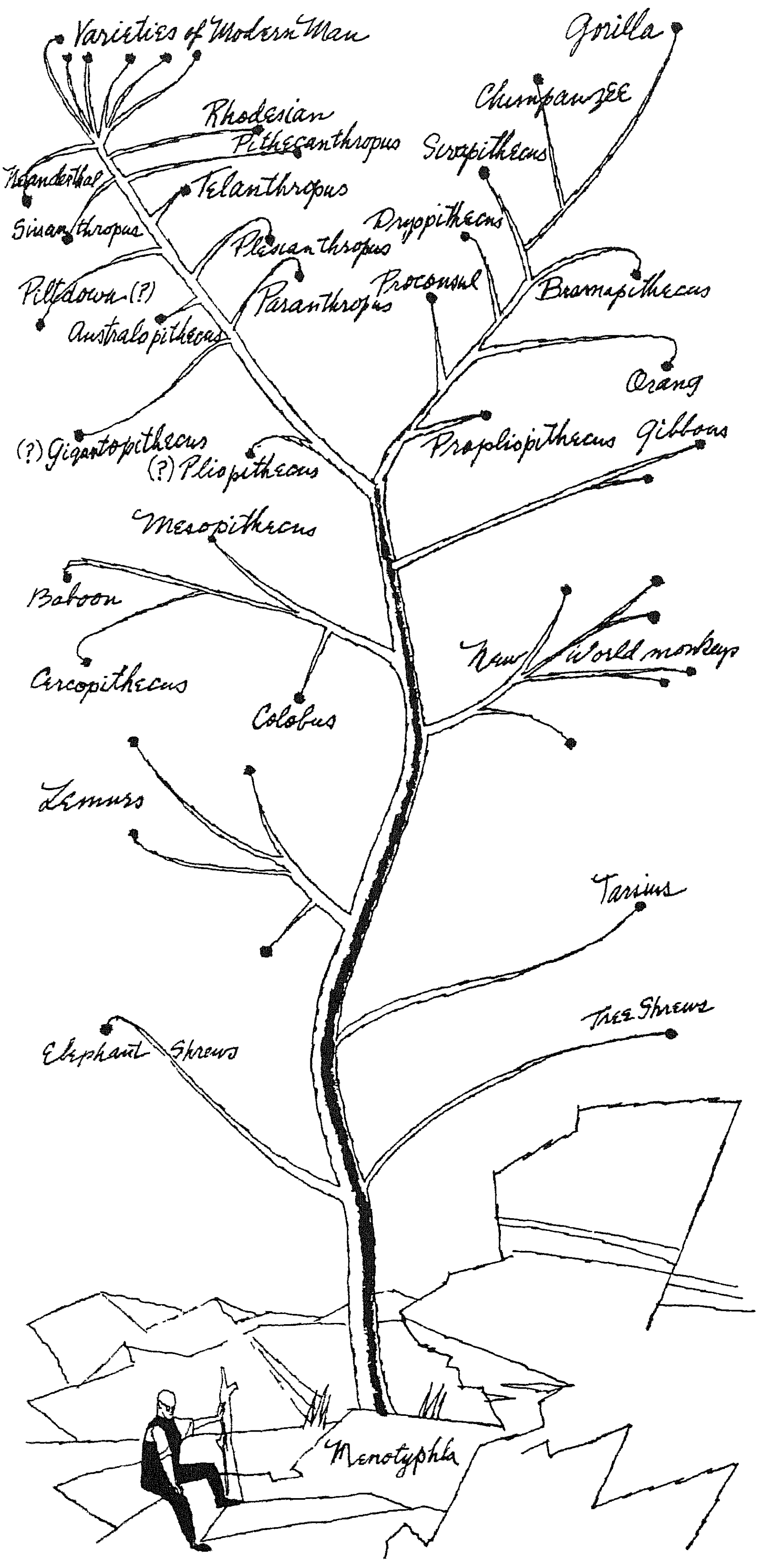
A month later Robinson made an even more important discovery. In a pocket which must be of later date than the Swartkrans jaw, he found what appears to be a human jaw. Though the molar teeth are a little larger than in *Homo sapiens*, they are not unlike those of the Java early man, Pithecanthropus. The ramus of the jaw is rather slender, and as the ascending ramus is low, we may assume it to be probable that the brain is nearer to the human type than in the ape-men.

Since I returned to South Africa several months ago we have discovered three fairly complete but badly crushed skulls of the Swartkrans ape-men. It is impossible yet to estimate the size of the

RELATIONSHIPS between the skulls, jaws and thigh bones of several primates are shown in the drawings on the opposite page. The cranial capacity of Plesianthropus is not much larger than that of the chimpanzee, but the characteristics of the skull are rather similar to those of Rhodesian man. The jaws of Paranthropus and Plesianthropus are more massive than that of man. The thigh bone of Plesianthropus is more like man's than that of the chimpanzee.



Homo rhodesiensis
Australopithecus africanus
Chimpanzee
Plesianthropus Transvaalesis
Plesianthropus Transvaalensis
Homo Sapiens
Homo Sapiens
Chimpanzee
Paranthropus crassidens
Plesianthropus Transvaalensis
Chimpanzee



PRIMATE FAMILY TREE, as proposed by Dr. Broom, places the ape-men Australopithecus, Paranthropus and Plesianthropus on the main branch of human descent. The modern apes came from a fairly early offshoot.

brain, but most likely it will prove to be over 700 c.c.

Meanwhile, at the Makapan Caves about 180 miles farther north, Dart's party, working under the Bernard Price Institute, has made discoveries of equal importance. They have found a fine occiput (rear of the skull) of a female, part of a face, a good lower jaw of a young male, and part of a pelvis of perhaps the same young male. These are ape-men of a different type. Dart has called the genus *Australopithecus prometheus,* meaning fire-maker. I agree that it is a new type of ape-man, but I do not think there is any good evidence that he made fire. And I am not satisfied that the supposed bone implements are really implements, as Dart holds.

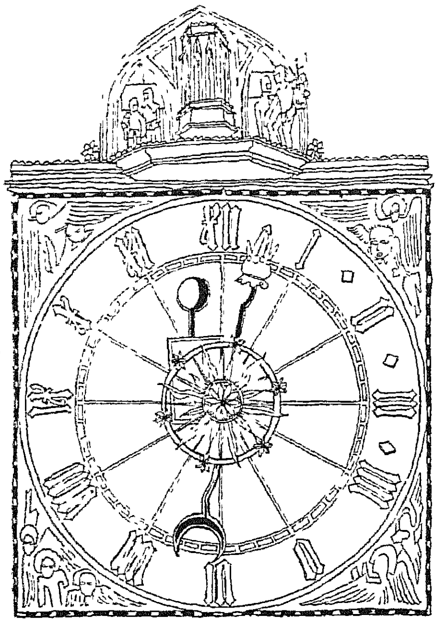
As the case stands at present, we have conclusive evidence that a family of higher primates which were practically human, but with relatively small brains, lived in South Africa for probably hundreds of thousands of years. While some hold that our various ape-men are all varieties of one species, my own conclusion is that there are five distinct types. I think it likely that some of the types date from the Upper Pliocene—and just possibly the Middle Pliocene. Others probably survived into the Lower Pleistocene. This dating is at present uncertain, some believe that most of our types are Pleistocene.

Quite certain it is that our ape-men ran on their hind feet, and that the hands were too delicate to have been used for walking. It seems probable that they dug out moles and hares with some kind of implement, and killed small baboons and dassies (the "conies" of the Bible) for food. If they made weapons and tools we may have to call them "men." In any case they were nearly men. And the small jaw recently discovered might be taken as a link between the ape-man and a true primitive man such as Pithecanthropus or the Heidelberg man. If so, the chain from a being that some consider to be an anthropoid ape to man would be complete.

But I personally do not think that the ape-men are anthropoids. I believe that the human line split off from the anthropoids at least as early as the Lower Oligocene, perhaps 25 million years ago, and that the nearest known type to man's remote ancestor is not a chimpanzeelike ape but the little fossil ape Propliopithecus of Egypt. I suggest that the ape-men of South Africa came on a different line from the higher apes, and that one of them became the ancestor of *Homo sapiens*

Robert Broom is curator of vertebrate paleontology and physical anthropology at the Transvaal Museum, Pretoria, South Africa.

SCIENCE AND



Announcement

AT 11 a.m. on September 23 President Truman announced the end of the U.S. monopoly in atomic bombs. His announcement that the U.S.S.R. had produced an atomic explosion was based on a careful evaluation by scientists of certain unspecified evidence. Although his communiqué touched off much speculation, the only authoritative information available to the public was Truman's statement and the official U.S.S.R. comment broadcast two days later by Tass, the Soviet news agency.

The President's full statement:

"I believe the American people to the fullest extent consistent with the national security are entitled to be informed of all developments in the field of atomic energy. That is my reason for making public the following information.

"We have evidence that within recent weeks an atomic explosion occurred in the U.S.S.R.

"Ever since atomic energy was first released by man, the eventual development of this new force by other nations was to be expected. This probability has always been taken into account by us.

"Nearly four years ago I pointed out that 'scientific opinion appears to be practically unanimous that the essential theoretical knowledge upon which the discovery is based is already widely known. There is also substantial agreement that foreign research can come abreast of our present theoretical knowledge in time.' And, in the three-nation declaration of the President of the United States and the Prime Ministers of the United Kingdom and of Canada, dated November 15, 1945, it was emphasized that no single nation could, in fact, have a monopoly of atomic weapons.

"This recent development emphasizes once again, if indeed such emphasis were needed, the necessity for that truly effective and enforceable international control of atomic energy which this Government and the large majority of the members of the United Nations support."

The text of the Tass statement, broadcast in English from Moscow:

"On September 23 Mr. Truman, President of the U. S. A., announced that according to data of the Government of the U. S. A., during one of the recent weeks there had occurred in the U S.S.R. an atomic explosion. Simultaneously, a similar statement was made by the British and Canadian Governments.

"Following the publication of these statements in the American, British and Canadian press and also in the press of other countries, there appeared numerous utterances which spread alarm among broad social circles.

"In this connection, Tass is empowered to declare:

"In the Soviet Union, as is known, building work on a large scale is in progress—the building of hydroelectric stations, mines, canals, roads, which evoke the necessity of large-scale blasting work with the use of the latest technical means.

"Insofar as this blasting work has taken place and is taking place pretty frequently in various parts of the country, it is possible this might draw attention beyond the confines of the Soviet Union.

"As for the production of atomic energy, Tass considers it necessary to recall that already on November 6, 1947, Minister of Foreign Affairs of the U.S.S.R. V. M. Molotov made a statement concerning the secret of the atom bomb, when he declared that this secret was already long ago nonexistent.

"This statement signified the Soviet Union already had discovered the secret of the atomic weapon and that it had at its disposal this weapon.

"Scientific circles of the United States of America took this statement by V. M. Molotov for bluff, considering that the Russians could not possess an atomic weapon earlier than the year 1952. They, however, were mistaken, since the Soviet Union possessed the secret of the atomic weapon already in 1947.

"As for the alarm that is being spread on this account by certain foreign circles, there are not the slightest grounds for alarm.

"It should be pointed out that the Soviet Government, despite the existence in its country of an atomic weapon, adopts and intends adopting in the future its former position in favor of the absolute prohibition of the use of the atomic weapon.

"Concerning control of the atomic weapon, it has to be said that control will be essential in order to check up on fulfillment of a decision on the prohibition of production of the atomic weapon "

Name and Place Unknown

IN the absence of a "Smyth Report" from the U.S S.R., the Russian atomic explosion generated a remarkably confusing crop of descriptions of the Soviet atomic energy enterprise, which, for want of a more authoritative name, may perhaps be called the Moscow Engineering District. These accounts, garnered by the Western press from sources ranging from unnamed Washington informants to "a Yugoslav recently returned from the Soviet-Iranian border," made up in circumstantial detail what they lacked in authority. They produce the following picture:

"Atomgrad," the Soviet center of atomic energy work, is variously located "a few miles north of Erivan" in the Caucasus near the Soviet-Turkish border; at "Ukhta, deep inside Russia", near Tobolsk, in central Russia; "beyond the Urals"; "in eastern Siberia."

The power of the Soviet explosion is described by one source as less than that of the Alamogordo bomb and by others as greater than that of any U.S. atomic bomb except the latest ones tested at Eniwetok.

The date of the explosion is stated on reliable authority to have been July 10, early in August, around September 1, and September 12. "Reliable sources" in Paris declare that French engineers recently detected not one but three atomic explosions in Russia.

The explosion was detected in (a) Germany, (b) France, (c) Iran, (d) Scandinavia, (e) Japan, or perhaps (f) Alaska. According to *Time*, "patrolling bombers, sniffing at the winds that blow out of Russia, picked up the radioactive cloud [and followed it] for thousands of miles."

The Russians learned how to make the bomb from the Smyth Report and/or spies in the U.S., Canada and Britain. Alternatively, or concurrently, they have had an atomic bomb project of their own since 1943, under the direction of NKVD Chief Lavrenti P. Beria, who would thus be the General Groves of the Moscow Engineering District.

The most detailed report, published in the Paris newspaper *Figaro* under the by-line of a Yugoslav traveler to Iran, describes "Atomgrad" as a collection of huge underground laboratories in the valley of the Sanga River 30 miles northeast of Erivan. Built in 1946, it has

THE CITIZEN

70,000 workers, among them 15,000 scientists and technicians, employed in four separate sections. 1) preliminary refining of uranium, 2) purification of uranium, separation of U-235 and extraction of plutonium, 3) plutonium research laboratories, 4) a medical research center. Each section is surrounded by a high concrete wall and no one is ever discharged or allowed to leave. The Soviet's decision to place its atomic energy project in this vulnerable region near the borders of Turkey and Iran is explained on the ground that the U.S.S.R. had no other convenient water-power sites available

How much truth there may be in this potpourri of rumor only the Soviet Government and perhaps some U.S. and British intelligence officers know. The secrets of the Soviet work in atomic energy since the war certainly have been as closely guarded as those in the U.S. Outside of intelligence circles and the custodians of high policy to whom they report, no data are available for any kind of informed guess as to how the Russians managed to build an atomic bomb so soon and what the scale of their present operations is.

Certain facts, however, are known. The underlying scientific principles and some of the technological requirements for a uranium chain reaction were widely discussed among European physicists as early as 1939. Since the war U. S. atomic energy officials have unearthed and translated a number of early technical papers by European workers which show a surprising knowledge of the problems later tackled by the Manhattan District. Thus a German physicist, S. Flugge, late in 1939 published in *Naturwissenschaften* a paper called. "Can Nuclear Energy Be Utilized for Practical Purposes?" In it he discussed the conditions for a chain reaction, the amount of energy that would be released, the measurement of the uranium capture cross-sections for thermal neutrons, the absorption of neutrons by fission products, the critical size of a bomb. The Russians were not behind the Germans in the investigation of atomic energy. At a meeting of the Soviet Physical Society in June, 1941, Soviet physicists presented seven papers on nuclear fission. These showed that the state of their knowledge in this field was close to that in the U. S. at the time.

It is known that at the end of the war the U.S.S.R. had a nucleus of first-rank physicists for nuclear research, including Peter Kapitza, Abram Yoffe, Y. I. Frenkel, Igor Tamm, P. I. Lukirsky, Lion Landau, Pavel Cherenkov and Dmitri V. Skobeltsyn. It is also known that after the war the Soviet Union recruited several German atomic physicists, among them Gustav Hertz, winner of the 1925 Nobel prize in physics. The U.S.S.R. launched intensive uranium mining operations, involving many thousands of workers, at the famous pitchblende mines of Joachimsthal, Czechoslovakia, and in Saxony, Germany

It was upon these facts, and upon an appraisal of the technical problems to be solved and the general state of Russian technological development, that U.S. atomic scientists based their estimate that the Russians would achieve an atomic bomb in 1952. The fact that they achieved it in a much shorter time means, as Samuel K. Allison of the University of Chicago has said, that the U. S. must "revise radically upward" its estimation of Soviet technology.

Detection

As far as detection is concerned, the difference between the first atomic explosion in history, at Alamogordo, N. M., and the ninth, somewhere in the U.S.S.R., was like the difference between an infant's initial oblivion to fire and its later experienced recognition. When one knows the signs to look for, a faint smell of burning or a wisp of smoke may be evidence enough. The experience gained from the observation of the eight atomic explosions from Alamogordo to Eniwetok undoubtedly was sufficient to enable U.S. lookouts outside the U.S.S.R. to detect evidence of an atomic explosion in that country. It is safe to say that President Truman's announcement was based on an unambiguous accumulation of cross-checked evidence, possibly gathered from a number of stations.

Obviously Geiger counters gave the most important evidence (aside from possible espionage). An atomic blast such as the one at Hiroshima releases an amount of radioactivity equivalent to that of 1,600 tons of radium. The clouds of radioactive material, made up of some 50 different types of atoms, emit a variety of radiations—neutrons, alpha particles, beta rays, gamma rays From the standpoint of long-range detection, only the beta rays are of much importance. Neutrons quickly disappear from the radioactive clouds; within a second after the explosion, most of them have been absorbed by hydrogen, nitrogen and other gases of the air. Alpha radiation also is relatively temporary in the clouds, for alpha particles come mainly from unfissioned uranium atoms, which are so heavy that most of them soon settle to the earth. Thus the traveling clouds of radioactivity are reduced largely to masses of relatively light fission products,

emitting beta particles. A Geiger counter equipped with a window that screens out the alpha rays from naturally radioactive elements in the earth is extremely sensitive to the beta radiations of atomic bomb fragments in the air.

The problem is to distinguish such radiation from the normal "background" of cosmic rays at the place where the counter is located. Cosmic radiation varies with latitude, longitude and altitude above the earth. At the 40th latitude, that of San Francisco and New York, the cosmic-ray background at sea level averages about 10 to 15 counts a minute in a counter of ordinary size. In a plane at 40,000 feet the background count rises to 800 to 1,200 a minute, and balloons at 60,000 to 70,000 feet have recorded counts of 3,000 and more per minute. A recording of radiation which is more than 20 to 30 per cent above the normal background at any location would, in the absence of any known explanation, be considered significant evidence of an atomic explosion.

How far might a radioactive cloud drift before it thinned out to the stage where it could no longer be detected? Reports published in *The Physical Review* after the New Mexico and Bikini tests give some idea of the range of detection. About 59 hours after the Alamogordo bomb exploded on July 16, 1945, A. W. Coven at the Naval Academy in Annapolis—some 1,400 miles away—found that the air's radioactivity had nearly doubled. Some 108 hours after the first Bikini explosion, G. Herzog of The Texas Company's Geophysical Laboratory in Houston, 6,800 miles away, observed sharp increases in radiation which lasted several hours. Thus the range of detection of an atomic explosion, given favorable wind conditions, may conceivably be as much as several thousand miles.

Much less helpful than the Geiger counter, but useful for checking its evidence, are the seismograph and the microbarograph. After counters picked up an increase in radiation, seismologists would look back at the shocks recorded on their seismographs during the suspected period of the atomic explosion. A blast near the surface of the earth can be distinguished from a deep earthquake. An earthquake produces, among other vibrations, "S" or "shake" waves, which oscillate at right angles to the direction of forward motion. A surface explosion produces no shake waves, but mainly "P" or "push" waves, oscillating like those of sound. However, a seismograph obviously cannot identify the cause of an explosion, and its detection range is limited; the Alamogordo bomb just barely registered on seismographs at the California Institute of Technology about 700 miles away.

The microbarograph, a standard weather instrument that can measure air-pressure changes of a fraction of an ounce, might provide additional confirmation by recording atmospheric shock waves. This device picked up the blasts of the New Mexico test more than 700 miles away in California, and its range has since been extended.

There remains another possible detection method—analysis of samples of air for radioactive fission products, such as were detected in Indiana-manufactured strawboard contaminated by particles from the Alamogordo bomb (SCIENTIFIC AMERICAN, October 1949). Studies of such samples might help to identify the fissionable material used in the bomb. If the site of the blast could be located by means of seismograph triangulations and knowledge of the speed and direction of winds carrying radioactive particles, a rough estimate of the power of the burst might be made by comparing the intensity of radioactivity with similar long-range measurements from the New Mexico, Bikini and Eniwetok tests. But these are all simply speculative possibilities; there is no indication of how much information the U.S. actually has on the Soviet explosion.

Electronic Printing

FOR some 60 years the basic machine in modern printing has been the linotype, which prepares written material for printing by setting, or casting, it on metal type-slugs. Recently a new machine which may replace the linotype and thereby revolutionize printing techniques was given its first public exhibition. It is an electronic device that dispenses with type altogether: by an ingenious combination of electricity and photography it produces printed lines on film from which engraved plates are made for the printing presses. It is claimed that the machine is four times as fast as the linotype and that eventually it will cut printing costs in half.

Like the linotype, the new electronic machine is operated by a compositor at a keyboard. On a linotype machine, the operator presses the keys to release matrices, or molds, of the desired letters, a moving belt carries the matrices to an assembly box, and after they form a complete line, which the operator "justifies" by adjusting the spacing of the words, he presses a lever to drop the matrices into a mold and a plunger presses molten lead against them to cast the line. The new electronic machine, on the other hand, is almost entirely automatic. The operator simply sets a dial for the desired length of the line and then composes the line by pressing the keys, arranged as on a standard typewriter keyboard. When he presses a key, he creates a pattern of electrical impulses representing the character. These successive signals collect in a storage or memory unit using telephone-type relays like those in a calculating machine; the storage unit automatically counts up the

characters until they complete a line, justifies the line and then sends the set of signals on to the next stage. There the signal for each letter triggers a combined camera and flashing stroboscopic light so that the camera at the correct moment photographs the appropriate letter from a synchronized spinning glass disk containing all the keyboard characters. The finished line appears as a strip of developed film. The entire process is completed within five seconds. As the operator types, the characters are also printed on ordinary typewriter paper, so he can see what he is composing and make corrections by "rubbing out" the wrong signals. When a full column of lines is set, the photograph is ready for engraving.

The machine was demonstrated in Cambridge, Mass., by the new Graphic Arts Research Foundation, whose work is supported by 139 newspapers, printing firms and other interested groups. Based on designs developed during the war by two French communications engineers, René A. Higonnet and Louis Moyroud, the machine has been developed to its present stage by Vannevar Bush and his associates at the Carnegie Institution, in collaboration with the two engineers. Because the printed film it produces must be converted into an engraving to be usable on a printing press, the device thus far is considered practical only for rotogravure printing and some forms of lithography. Its application to letter-press printing will depend on improvements to reduce the cost of engraving. Commercial versions of the machine are expected to be on the market within 18 months. Its developers say that it will compete in price with linotype machines, which range from $5,000 to $17,000.

Climate and Houses

As every meteorologist knows, there is no such thing as an "American climate." The climates of the various regions of the U.S. resemble those of places as diverse as New Zealand, Great Britain and Japan. Yet most U.S. families, to the chagrin of architects, cling stubbornly to a standard American architecture. People insist on building the same Cape Cod cottages in Alabama, Kansas and California.

To help introduce some climatological science into home-building, the editors of *House Beautiful* decided to put the existing technical information on the subject into palatable form for consumers. For two years a staff of consultants under the direction of Paul Siple, military geographer for the Army General Staff, has been analyzing facts on the climates of 117 U.S. cities which were collected by the W.P.A., the U.S. Weather Bureau and the American Society of Heating and Ventilating Engineers. In the magazine's October issue, and at a recent

forum in New York City, Siple's group presented some of its findings and conclusions. It pointed out that a homebuilder should consider the "macroclimate" of the region, the "microclimate" of his plot and the "kryptoclimate" inside the house itself.

The experts explain how the seasonal amounts of rainfall, wind, humidity and sunshine and temperature ranges should determine the design of a house. In Columbus, Ohio, for example, the temperature will be between 65 and 85 degrees 28.1 per cent of the year, which means that "28.1 per cent of over-all design emphasis should be on open-door and outdoor living facilities." As for microclimate, Helmut Landsberg of the Research and Development Board in Washington emphasized that the topography of the site may make a great difference in sunlight and temperature; the position of the house in relation to the sun can increase or decrease the amount of heat it receives by 85 per cent or more. Landsberg's own house, situated to minimize the summer heat of Washington, lies in a depression where a pool of sinking cool air lowers the temperature by as much as 10 degrees. The placing of hedges and other vegetation near the house also helps to control the microclimate. The kryptoclimate in the house is controlled by proper use of insulation, windows, and so on.

House Beautiful has published analyses of the Columbus region and suburban New York, and plans to cover 14 more American cities and their environs by July, 1951.

International Laboratories

THE ill-supported and much-criticized United Nations Educational, Scientific and Cultural Organization has proposed a dramatic group of projects for which it is about to seek approval from the UN. It seeks to establish a number of international research laboratories. A Committee of experts of UNESCO has chosen three projects for "highest priority"—an International Computation Center, an Institute for Neurophysiology and an Institute of the Human Sciences. Preliminary plans have been approved by the Committee on UNESCO of the U. S. National Research Council and by a group of advisers to the UN's Economic and Social Council. "The next move," says the NRC Committee, "is up to the Economic and Social Council."

The group unanimously agreed that an International Computation Center, equipped with modern mathematical machines, was a great need in Europe; because of the high cost of such machines continental European scientists have no computing laboratory. The center would be used not only in pure research but also in the study of statistical problems in economics, population and agriculture The Institute for Neurophysiology also was chosen to fill a need in a relatively uncovered field. The proposed Institute of the Human Sciences is intended to spread existing knowledge in the social sciences, and to conduct research on how to increase the effectiveness of international cooperation, including that of the UN itself.

Elements Renamed

THE naming of chemical elements, like the naming of babies and breakfast cereals, is governed more by inspiration than by logic. A new element is generally named by its discoverer, and he is bound by no rules. Since the same element may be given different names by independent discoverers, and even a universally acknowledged discovery may go by different names in different countries, a certain amount of confusion develops. The final authority for resolving these confusions is the Commission on Inorganic Nomenclature of the International Union of Chemistry. Recently the Commission met in Amsterdam, with representatives from 30 nations present, and made some official decisions.

The one that will cause the greatest readjustment in the English-speaking world is its renaming of tungsten, element 74. This commonly used metal is henceforth to be known in the U.S. and Britain, as it already is in other countries, as wolfram, after the mineral wolframite, from which it was first separated. The name will now be consistent with the element's chemical symbol, W.

The case of element 61, a rare earth, presented the Commission with a knotty problem. University of Illinois chemists, reporting its discovery in 1926, named it "illinium." Chemists at the University of Florence in Italy later claimed to have identified the substance more accurately, and they named it "florentium." In 1941 workers at Ohio State University gave it still another name, "cyclonium," after the cyclotron with whose aid they claimed to have isolated it. Finally chemists at the Oak Ridge hot chemistry laboratory discovered a fission product which was identified beyond question as element 61, and they gave it a fourth name—"prometheum," after the Greek god of fire. The Commission decided to accept this as the official name, but changed its spelling to "promethium."

Other rulings of the Commission:

Element 4, known both as beryllium and glucinium, is now officially beryllium.

Element 41, called columbium in the U.S., is to be called niobium, in deference to prevailing international usage.

Element 43 is to be technetium, the older name, masurium, is dropped.

Element 71 is to be lutetium instead of lutecium (it was named in 1907 after Lutetia, an ancient name for what is now Paris).

Element 72 is officially confirmed as hafnium.

Element 85, a naturally radioactive substance, is to be known as astatine, from the Greek "astasia" meaning unsteadiness, as suggested by University of California chemists in 1940.

Element 87 is francium, for France, where it was discovered in 1939.

Element 91 is protactinium instead of protoactinium.

Elements 93 to 96 are officially confirmed as neptunium, plutonium, americium and curium respectively.

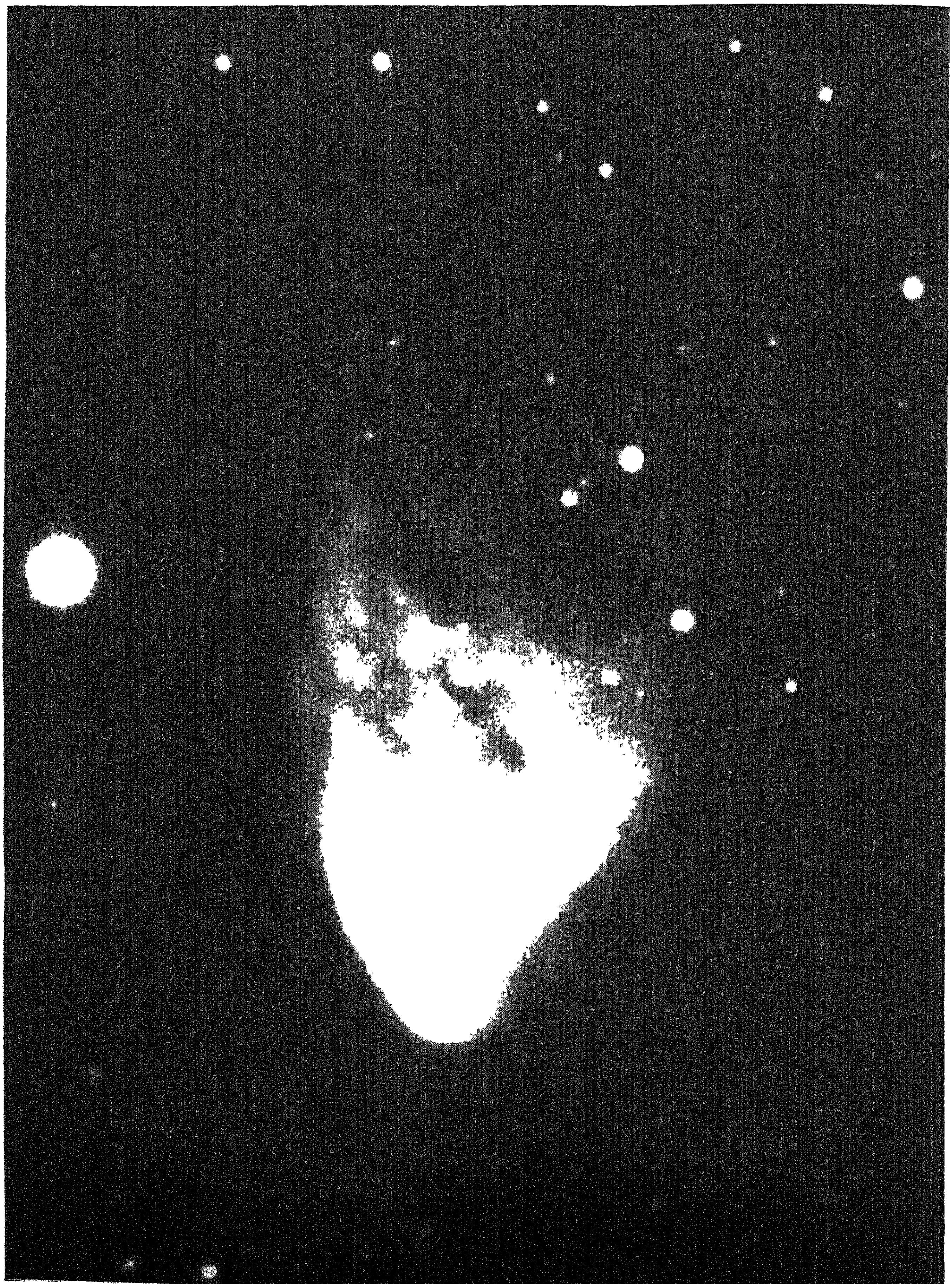
The Commission postponed for decision at a future meeting a proposal that the names of certain well-known elements be changed to agree with their chemical symbols. It was proposed that gold be called "aurum," sodium "natrium," tin "stannum" and potassium "kalium."

Safer Injections

THE injection of protein fluids into the veins as a method of emergency feeding has recently been widely adopted as a life-saving measure in many conditions—severe burns, starvation, gastric cancer, in preparation for major surgery, and so on. But protein shots are sometimes dangerous; they may produce allergic reactions and severe shock. This danger may be avoided by injecting amino acids, the building blocks of proteins, instead of the proteins themselves. The difficulty, however, is that an amino acid is made up of two types of molecules, called "l" and "d," and only the l-acids are desirable. The chemical separation of l-molecules from d-molecules is troublesome and costly.

Now it appears that a group of biochemists at the National Cancer Institute of the Public Health Service have solved the problem. Their discovery was a by-product of another investigation. The group, headed by Jesse P. Greenstein, needed a large supply of pure l-acids for a study of protein metabolism in cancer. It occurred to them that they might be able to separate the l-molecules from the d-molecules in amino acids by a biological technique using enzymes, which would be much simpler than the laborious chemical processes previously used. Digestive enzymes are known to act only upon the l-molecules in amino acids. The investigators mixed specially treated amino acids with animal tissues that contained enzymes. After allowing time for the enzymatic reactions to take place, they were able to extract pure l-acids with alcohol. By this method they have separated the l-molecules in 16 amino acids.

The process greatly reduces the cost of producing the l-acids and for the first time makes it practicable to use them in intravenous feeding. For example, a gram of l-methionine, which formerly cost $6.50, can now be made for 30 cents.



FIRST PHOTOGRAPH came from the 200-inch on January 26. It is a 15-minute exposure of NGC (an abbreviation of New General Catalogue) 2261 made under poor seeing conditions. NGC 2261 is a comet-shaped mass of gas illuminated by a star at its apex. It is in our own galaxy at a distance of a few thousand light-years.

FIVE HISTORIC PHOTOGRAPHS FROM PALOMAR

Presenting a portfolio of noteworthy plates made with the 200-inch mirror before it was dismounted from the Hale telescope for its final retouching

by Edwin P. Hubble

THE first photographs made with the 200-inch Hale telescope on Palomar confirmed the most optimistic predictions of its designers. They recorded nebulae at least four times as faint, and hence twice as far away, as had ever been photographed before. This early result was better than we had any right to expect, because the photographs were made at a time when further work still had to be done to bring out the full power of the mirror. When the mirror is adjusted to its maximum efficiency, its range should surpass all advance expectations.

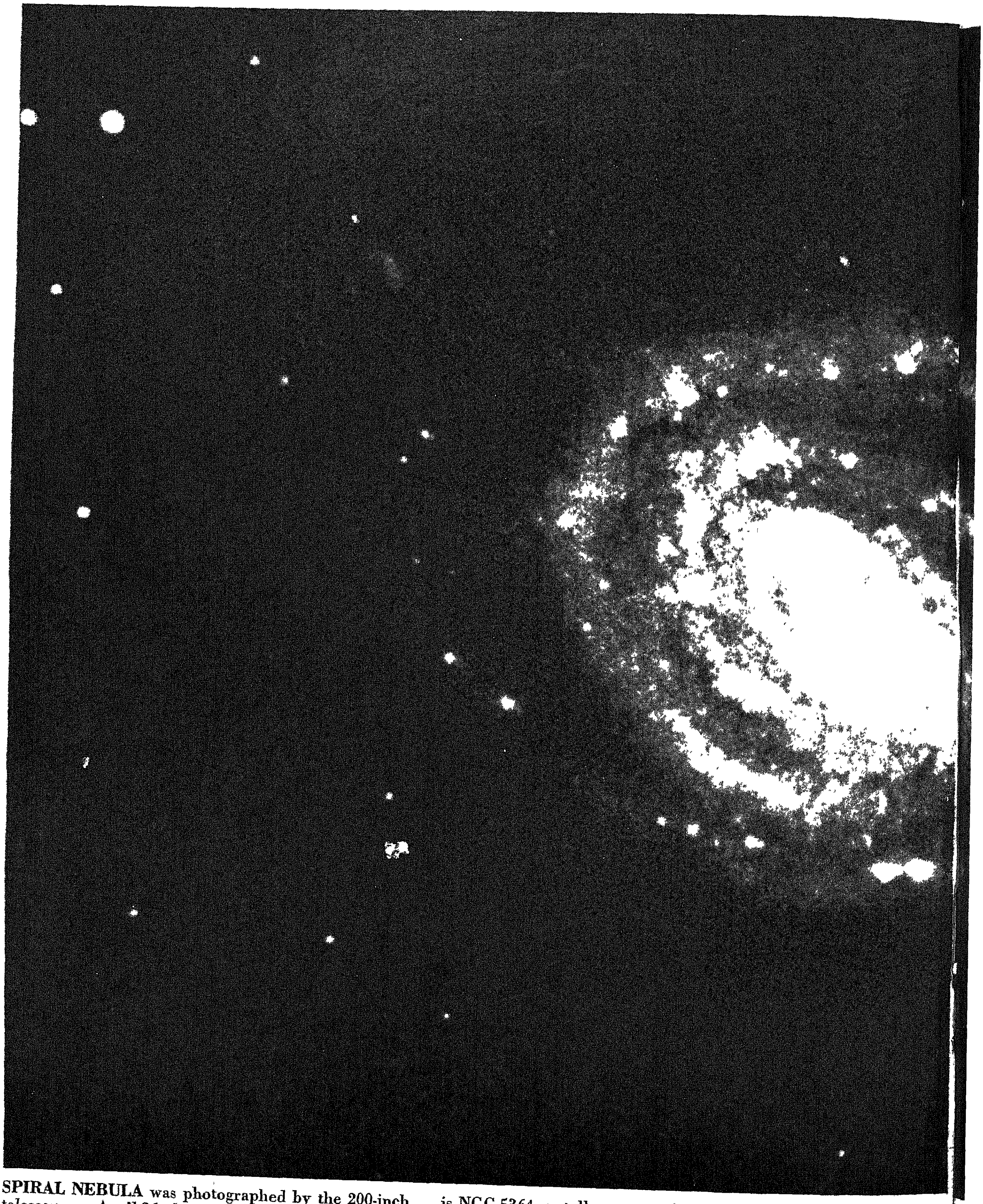
The 200-inch mirror, which weighs about 15 tons, must be supported so that it can be tipped from horizontal to vertical without sagging enough to distort the figure, or curve of the mirror-face, appreciably. Because the tolerances are measured in fractions of wavelengths of light, the adjustments are a tedious business, and they proceed more and more slowly as perfection is approached. The ultimate goal is to concentrate the light from a star in a circle at the focus of the mirror less than .002 inch in diameter (comparable with the resolution of fast photographic emulsions) regardless of how the mirror is tilted. At the start the images were about 10 times the desired size, *i.e.*, the resolution was only one tenth as sharp as our goal.

THE effectiveness of a telescope depends on two qualities: its light-gathering power and its resolution. The first obvious adjustments brought the 200-inch to its full light-gathering power. At that stage the telescope could have been used efficiently for any research work that did not require fine definition. Further adjustments soon reduced the optical images to the limit of resolution on nights of poor "seeing," that is, when the twinkling and dancing of stars is so great that, magnified by the telescope, they produce large images on the photographic plate. By the end of 1948 still further adjustments had refined the optical images to the point where they were only about twice the desired size, and the telescope was considered to be ready for work under average seeing conditions. It then became obvious that to make further progress, so the telescope would be sharp enough to take advantage of the very finest seeing conditions, would require a major operation on the mirror.

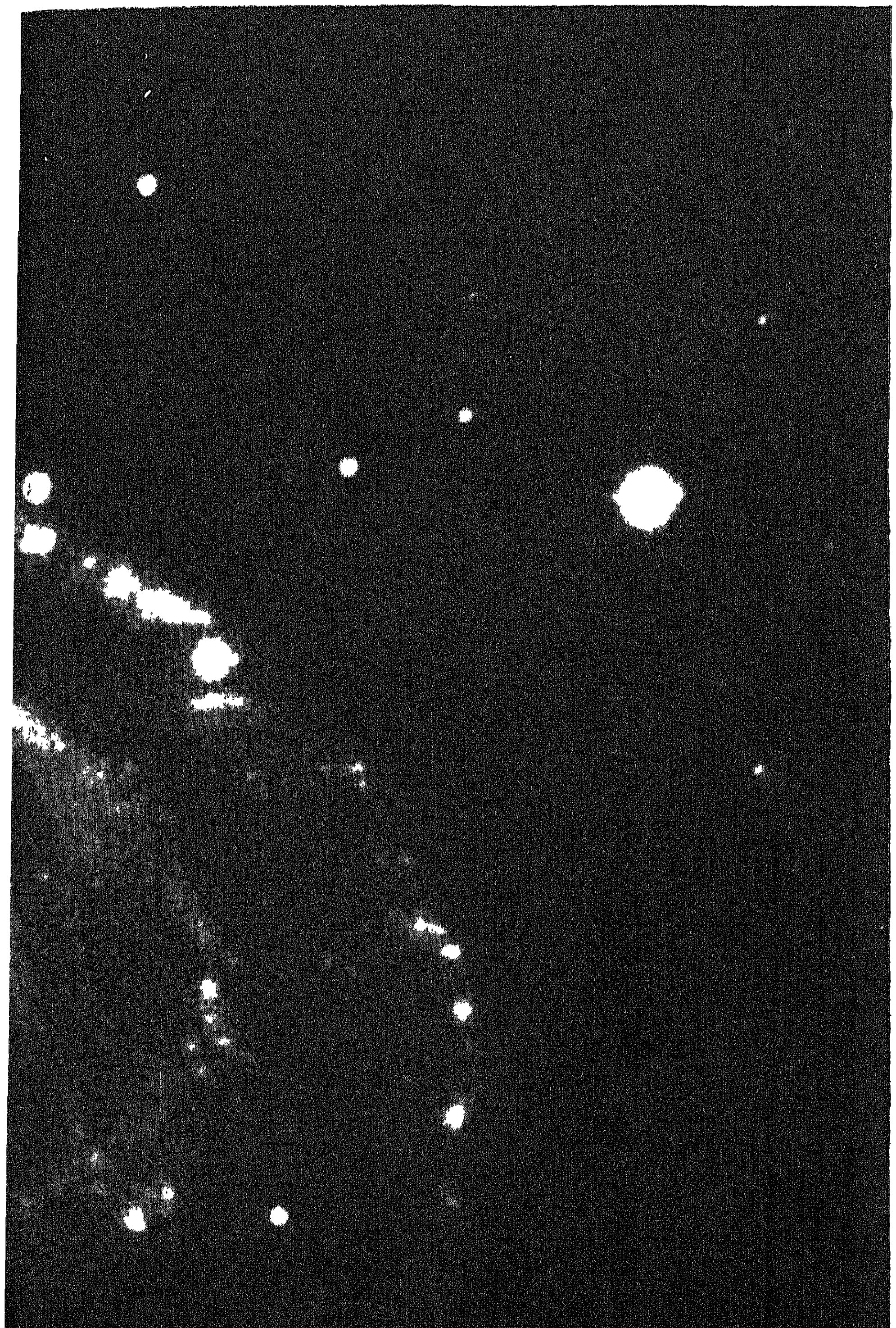
The trouble was in the figure of the mirror. The outermost 18-inch zone was too high by a few millionths of an inch, and it could not easily be bent into shape by the supporting mechanism. So it was decided to "retouch," that is, to rub down the offending zone. For this work the mirror was dismounted and laid on the floor of the dome and its aluminum reflecting coat was removed. The rubbing had to proceed very cautiously in order to avoid undercutting the proper figure. Each two-hour session of rubbing was followed by two weeks of testing on the telescope. This job, which began last May, has now been completed, and the telescope will again be ready for use this fall.

Before this operation was performed, some 60 photographs were made to record the performance of the telescope as it was at the time. It is these photographs, the first to be made under normal observing conditions, that constitute the product of the 200-inch to date. About half a dozen of them represent the full power of the telescope under average seeing conditions. Some of the most significant photographs are shown on these pages.

The first photograph with the 200-inch (*opposite page*) was made on January 26, 1949. It was a 15-minute exposure under poor seeing conditions of the galactic nebula NGC 2261. This ex-



SPIRAL NEBULA was photographed by the 200-inch telescope on April 26, shortly before the mirror was removed and its outer 18 inches rubbed down. The nebula is NGC 5364, a stellar system about seven million light-years away from our own. Even at this distance the 200-inch mirror is able to resolve a few of the brightest



stars in the system for individual study. This photograph has been enlarged 7.5 times from the original negative, demonstrating that relatively fine detail was achieved by the 200-inch mirror even before it was retouched.

posure was made merely as a preliminary trial of operations and mechanisms involved in working in the prime-focus cage—a six-foot barrel suspended in the top of the telescope tube, directly over the center of the main mirror. Everything worked perfectly, but the images were so large, due to the poor seeing, that the plate has no great scientific value. It will be preserved largely for sentimental reasons.

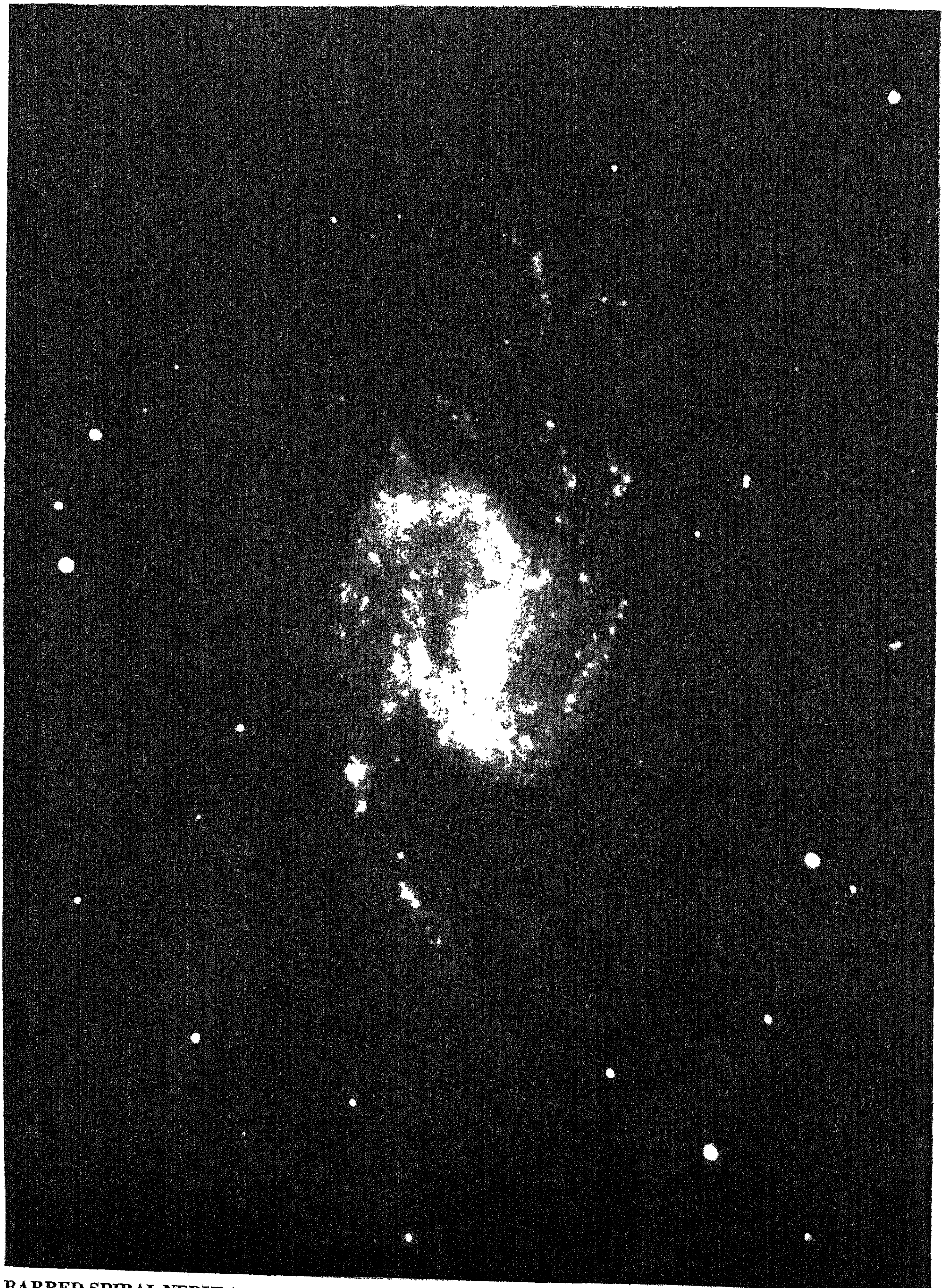
The following night, with seeing improved but still below average, several series of short exposures were made with different apertures to study the star images. There were also a few longer exposures of well-known nebulae, made to determine the maximum exposure possible without too great interference from the faint luminosity of the sky background. The limit with full aperture, using the very sensitive Eastman Kodak emulsion 103-a-0, was found to be about one hour. Longer exposures would merely fog the plates without registering any fainter objects.

WITH these preliminary tests completed, the observer settled down to wait for better weather. January was a stormy month. He had waited a week for the first plates, and the clouds had closed in once more. Four days later, January 31, the opportunity came. The night was clear. Although the seeing was poor at the start, it improved steadily, and during the last three hours before dawn it could be rated as average. The critical tests were made during these hours.

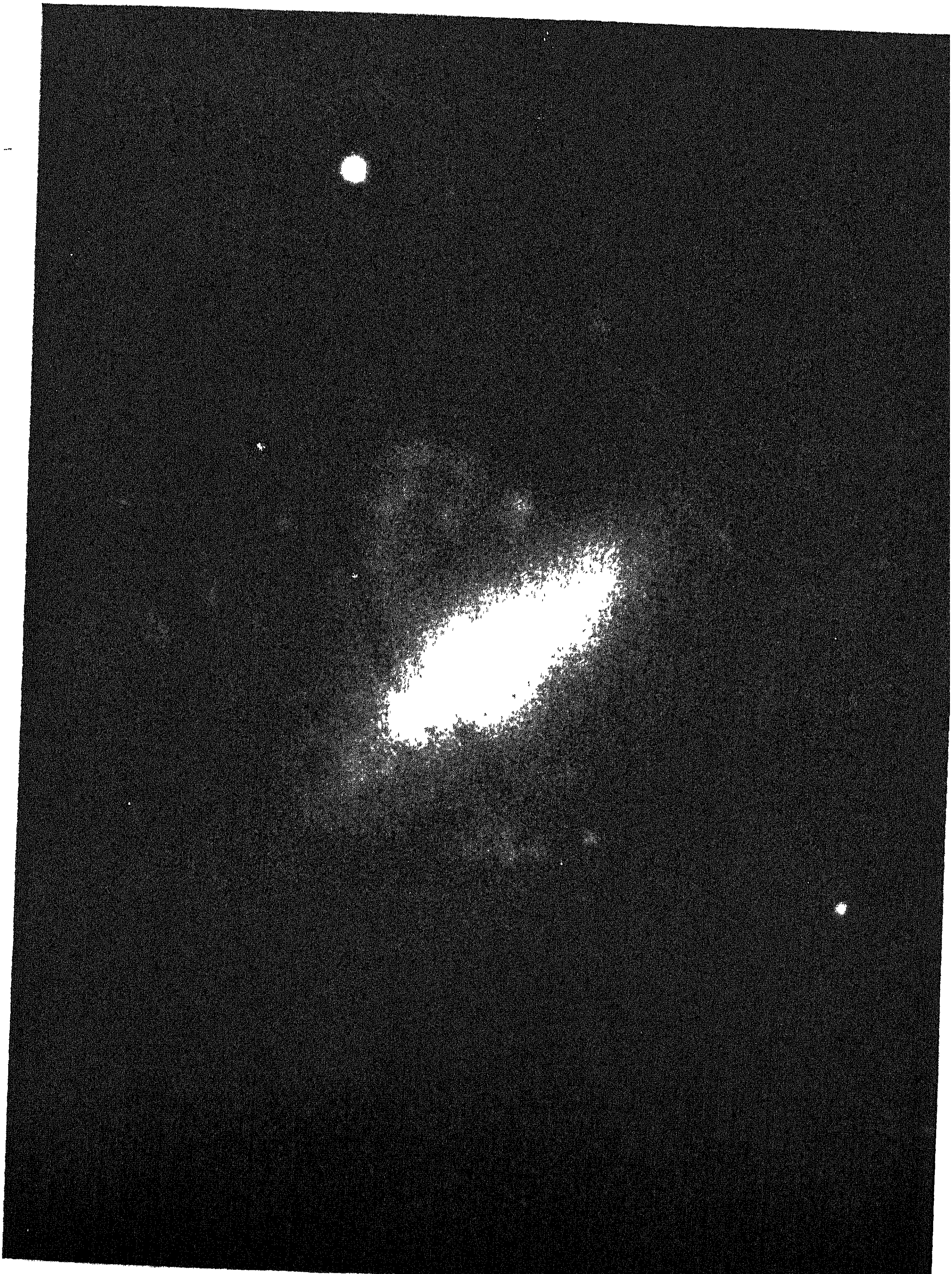
Selected Area No 57, a random sample of the sky in Coma Berenices, near the pole of the Milky Way, had been chosen as a suitable test field. It had been thoroughly studied beforehand, and accurate measures of apparent brightness had been established for a sequence of increasingly faint stars, reaching to the limits of the 100-inch reflector on Mount Wilson, the largest telescope theretofore in operation. On this night, as in the preliminary test, short exposures were made with different apertures, and another set was made with increasing exposure times at the full aperture.

It was found that with apertures up to 160 inches, the faint-star images were as small as the seeing permitted, but with full aperture they were perceptibly larger (about .003 inch). This degree of spreading of images was expected; it was accounted for by the imperfect edge of the mirror, and it will be corrected by the retouching of the mirror that has just been completed.

The most welcome result of the test was the faintness of the stars recorded on the plates. The faintest stars that the 100-inch telescope had been able to record with the longest possible exposures were registered by the 200-inch after



BARRED SPIRAL NEBULA was photographed by the 200-inch on April 27. It is NGC 3359, a stellar system about six million light-years away. Here, as in the photograph on the preceding two pages, the 200-inch mirror has resolved a few individual stars. These may now be compared with the brightest stars in our own galaxy.



EARLY-TYPE SPIRAL NEBULA was photographed on January 31. It is NGC 2685, a system about five million light-years away. Nebulae of this type do not contain supergiant stars such as are found in the late-type spirals. Thus the brightest stars in this nebula are not resolved. Original plate has been magnified 17.5 times.

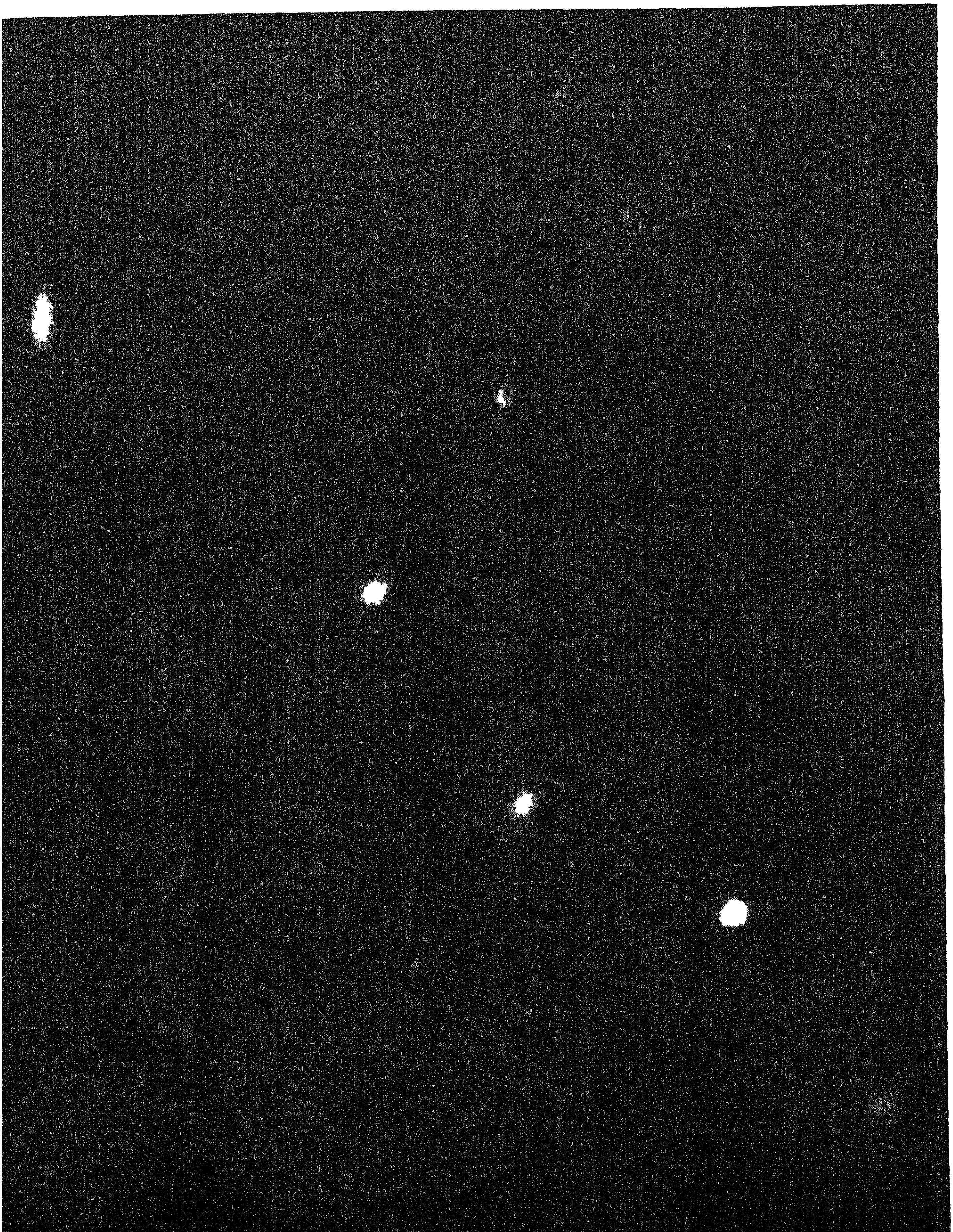
exposure of only five to six minutes In a full exposure of 60 minutes, the 200-inch accumulated 10 to 12 times as much light as in the shorter exposures. This does not mean that it could reach stars 10 to 12 times fainter, for the nature of photographic processes limits the rate of image-making. It did, however, reach stars which are estimated to be at least four times fainter than the extreme limit of the 100-inch. This achievement, which represents the ratio of the light-gathering power of the 200-inch to the 100-inch, was all that had been expected, even with the best definition. Evidently our predictions had been overcautious, for the 200-inch will eventually do much better than this. With a clean mirror (the tests were made with a rather grimy coat) and the correction of the mirror that we have since made, it should be possible to reach stars perhaps 20 per cent fainter than those recorded in last January's test. In astronomical language, the 200-inch should reach and possibly surpass the 23rd photographic magnitude—stars more than 600 million times fainter than the faintest that can be seen with the naked eye.

EVEN MORE impressive than the faint stars on the photographs were the faint nebulae. These nebulae are great stellar systems, similar to our own system of the Milky Way. They are scattered thinly through the universe out as far as telescopes can reach. With long exposures the 200-inch registers many more nebulae than stars—evidence that the great telescope breaks clean away from our own stellar system and ranges through the very depths of space. The faintest nebulae recorded appear as ghostly spots only a little larger than the images of stars. Twice as far away as any identified with the 100-inch, most of the threshold objects presumably are average stellar systems at distances of the order of a thousand million light-years from us. Some perhaps are giant systems even more remote; a few may be dwarf systems closer to us. All of them are inhabitants of space beyond the reach of the 100-inch—space hitherto unexplored.

Our photographing with the 200-inch continued through April The later photographs confirmed, in a general way, the results of the first critical tests. The tests show quite clearly that the 200-inch opens to exploration a volume of space about eight times greater than that previously accessible for study. The region of space that we can now observe is so substantial that it may be a fair sample of the universe as a whole.

Edwin P. Hubble is Astronomer and Chairman of the Research Committee at the Mount Wilson and Palomar Observatories.

GREATEST PENETRATION OF SPACE was achieved by the 200-inch telescope on January 31. This plate shows Selected Area No. 57, a random sample of the sky in the constellation Coma Berenices. It is a 60-minute



exposure representing the maximum power of the telescope under average seeing conditions. The plate shows a few stars and many nebulae. The latter appear as the smaller fuzzy spots. These nebulae are full-scale stellar systems. The faintest of them are at distances that average approximately a thousand billion light-years.

VISIT TO ENGLAND

Being an account of the author's call upon the group of noted physicists at the universities of Manchester and Birmingham. Second in a series of three articles

by Leopold Infeld

IN DUBLIN the sky had been blue, the air clear, the grass green, the waters sparkling. But two hours later, when we circled over London, sky, air and city were as gray as the problems of England.

I had first seen this monstrously large city some 15 years before when I arrived to spend two years at Cambridge. London then had seemed to me magnificently rich, though brooding and somewhat graceless. This time the impression of wealth was gone. London was shabby, its houses in need of paint, its inhabitants in need of a tasty meal, its hotels in need of soap and towels But, to use a platitude, everything is relative. After a three-day stay in England I went on to Poland. When I returned four weeks later from the ruined Continent, London actually seemed blooming with opulence. Compared with Berlin, Warsaw and Wroclaw, the effects of bombing on London appeared neglıgible.

Before I left for Warsaw, the Polish Ambassador in London and his beautiful wife gave a dinner party for me, to which they invited scientists. I was especially pleased and honored that the well-known physicists P. M. S. Blackett and Leon Rosenfeld accepted the invitation and came all the way from Manchester to the dinner. I must admit that if I were living in England and knew the quality of the Ambassador's dinners, I too should have accepted such an invitation, no matter what bores I might meet. Before I went to England I had no idea that food could be so important. It is not so much the scarcity of food that gets on one's nerves as the tasteless way it is cooked and served. Every successive meal becomes a new ordeal, increasingly difficult to face. One of my friends used to say before the war that the English built an empire because they were not interested in good food or love-making and had nothing else to do. Today both empire and food seem to have deteriorated in the same degree. (I don't know about the love-making.)

The dinner party was gay and informal. We talked late into the night. I had never met Blackett, whose name has recently become known to the general public as a winner of the Nobel prize and the author of a much-discussed book on the strategic consequences of atomic energy.

Blackett's book is very well written, and I am sure that no one who reads it can doubt the author's sincerity. Some of the reviews of the book, although written by first-class physicists, were touched with venom, and were not argued on that detached plane of reason on which people incorrectly imagine that scientists always operate. One of the reasons for the violent differences over the book is, of course, that Blackett's military arguments cannot be conclusively proved or disproved except by actual test in war. Blackett himself is aware that his argument that the atomic bomb is not a decisive weapon does not take into account the possibility of the use of poisonous radioactive gases which may prove more deadly than atomic bombs. This part of the book and the discussion around it seem to me fairly meaningless. The history of wars should have taught us by now that their realities are always different from the predictions of quarreling scientists and strategists. Perhaps an imaginative artist like H G. Wells has more chance of guessing right than a scientist.

Aside from these debatable arguments, Blackett's book contains some interesting ideas and information, which should prove stimulating even to those who disagree with the author. Most of the reviews said that Blackett favored the Russian plan and opposed the American plan for the control of atomic energy. I did not find this in the book. In fact, he has very warm words for the "Acheson-Lilienthal" plan, as distinguished from the later "Baruch" plan. Blackett contends that the original plan, formulated by men of vision and idealism, was taken out of their hands and used as a means of power politics.

From our discussion at the dinner table, it was clear that Blackett still believes every word he wrote, and that his critics have no more convinced him than he them. One spiteful remark often made about Blackett is that he is too far left of center to be objective—as though there were one precise, predetermined position from which objectivity is possible. To me it seems that Blackett's "lack of objectivity," if such a phrase has meaning here, stems from another source. He loves Europe, with its mosaic of nationalities, diversity of culture, and beauty of architecture. When Blackett gets to talking on this subject, one senses that he feels an individual pain and horror for the ruin of each beautiful and ancient building that was destroyed by indiscriminate bombing in the late war. No doubt these emotions color Blackett's arguments. Who can be free of them when he contemplates the question of war and peace?

Blackett and Rosenfeld asked me to visit the University of Manchester and lecture at its theoretical physics seminar on my return from the Continent. I gladly accepted the invitation.

AFTER a four-week trip to Poland, I came back to England for a one-week stay before going home to Canada. My first visit was to the University of Birmingham. I bought a first-class ticket from London to Birmingham. This turned out to be a mistake, as far as opportunities for conversation were concerned. European train compartments, with seats facing each other, are made for confessions. Passengers may unburden themselves of their life stories without running the danger of re-encountering their confessors. On the Continent conversation is inevitable, but the British are more reticent. Near me in the compartment to Birmingham sat two well-dressed gentlemen. They carried on a desultory discussion, punctuated by puffs on their pipes and tremendous stretches of silence. During the infrequent breaks in these dead pauses, they returned repeatedly to a single theme: the needs of the British Empire Their diagnosis was that "we did not send the right kind of people to Canada and Australia to build up trade," and that this situation must somehow be remedied. It was clear that they still regarded Australia and Canada as colonies, and only grudgingly recognized that the U. S. had ceased to be one. I felt a great urge to intervene in the conversation, but since on an English train this would have been an unthinkable barbarism, I man-

aged to remain silent all the way to Birmingham.

European cities can be breath-takingly beautiful (*e.g.*, Dublin, Cambridge, Cracow), but when a European town is ugly it is utterly so. Birmingham is ugly. The University of Birmingham, though pleasantly situated on a hill, with a spacious, green campus, has the ugliest university buildings I have ever seen in my life. The inhabitants of Birmingham console themselves by claiming that the University of Manchester is still uglier. This is not true. Birmingham's chief building is a red brick mosque with a tremendous glass cupola, flanked on one side by three wings with cupolas of decreasing size, and on the other by a single wing with one cupola. The opportunity to complete the structure and correct this lack of symmetry passed away with the Victorian era, for no one would dare suggest building more cupolas now to round out the picture. Yet to leave the building unfinished is no solution either. The chance to destroy the building by bombs during the war was missed, and I heard regrets on this score.

Dominating the Birmingham campus is a huge red brick tower, also in bad taste. This ugly structure is called by physicists "the Poynting vector." The term, well known to anyone who has studied the work of the 19th-century physicist James Clerk Maxwell, represents a concept introduced by the late John H. Poynting a famous professor of theoretical physics at Birmingham.

The department of theoretical physics, one of the world's best, is housed in temporary wooden barracks. It was refreshing to find the emphasis placed on men and not on buildings. The reputation of the school of theoretical physics in Birmingham is due largely to one man—Rudolf E. Peierls. He has a rare ability to stimulate others. A relatively young man of 42, he kindles his group by his talks, lectures, arguments, questions and ability to arrive quickly at the essence of a problem.

From Peierls, a German refugee from Nazism, I learned some interesting details about the British end of the atomic bomb project, in which he played a leading role, receiving in recognition the award of the Order of Commander of the British Empire. The idea of the atomic bomb was discussed by Peierls and Otto R. Frisch, another German refugee, as early as the beginning of 1940. Together with Sir James Chadwick, the discoverer of the neutron, they approached the British Government with the suggestion that the idea be studied. A Government-appointed Commission that included Blackett and G. P. Thomson decided early in 1941 that such a project was feasible. On the basis of what Peierls told me, it appears that the British started actual work on the bomb proposal before the U. S. The British

P. M. S. BLACKETT is professor of physics at the University of Manchester. He has also taught in the Cavendish Laboratory at Cambridge.

LEON J. H. C. ROSENFELD, theoretical physicist at the University of Manchester, has done most of his work on the Continent. He is a Belgian.

and U. S. projects did not merge until 1943.

Nowadays too many people are inclined to forget England's great contributions to the knowledge of the atomic nucleus. The golden age of atomic physics in England, when Lord Rutherford was alive, seems to me to outshine any other in the history of experimental science. The pioneer work done in this field at Manchester and later at Cambridge formed the foundations for the spectacular work of physicists in North America. Every scientist knows this. It would be well if everyone else, even Senators, remembered it. Although England today has neither the wealth nor the human scientific strength that has gathered in America, it still has great science and is ahead of us in the appreciation of it.

Birmingham's department of experimental physics has two full professors. The senior man is white-haired Marcus L. E. Oliphant, 48, one of Lord Rutherford's most talented students. He is a key man in England's experimental work on atomic physics. Unfortunately England will soon lose Oliphant, for he is returning in a year or two to his native Australia. The huge proton synchrotron under construction in Birmingham, designed to accelerate protons to 1.5 billion electron volts, is called "the white Oliphant." When finished, it will be the biggest, most effective accelerator in existence—provided it is completed before some of the larger machines in the U. S., as seems likely.

Our century is witnessing a race in atomic artillery which in the long run will have more significance than the vulgar competition in building atomic bombs. This race is the physicists' effort to build faster and faster atomic projectiles that will penetrate deeper and deeper into the nucleus, with the hope of finding out more and more about its structure and the forces that bind it together. "The white Oliphant," a colossal doughnut-shaped metal structure, is the latest word in the race so far, but no doubt it will soon become antiquated. At Brookhaven National Laboratory on Long Island and at the University of California, still more powerful proton synchrotrons, of three billion and six billion electron volts respectively, are being built. The one at Birmingham, however, seems to be further along in its construction. The physicists' atomic artillery not only is becoming more powerful, it also is growing in numbers, populating more and more physics departments and other laboratories throughout the world. Indeed, the fever of this "armament" race has created a danger that the machine will become a goal in itself, rather than a means of solving problems.

At Birmingham the theoretical and experimental work is focused on nuclear physics. Yet everything is open to inspection. There is no secret work on the campus. Indeed, nowhere in England's universities did I see guards watching over experimental laboratories.

FROM Birmingham I went to Manchester. I shall always regret that I spent such a short time there. The University of Manchester, like Birmingham, is situated in an ugly city. Its English Gothic walls are black with grime. Yet its distinction somehow shines through its external shabbiness.

It is impossible to describe briefly a physics laboratory that deals with as many problems as Manchester's. Blackett decided to concentrate our tour of the laboratories on the work in cosmic rays, for which Manchester is most famous. We climbed the high, elevatorless building by fire escapes to its flat roof, where some cosmic-ray experiments, using 14 Geiger counters, were in progress. The laboratory's equipment makes so many cosmic-ray photographs each day that a staff of specially trained girls is employed to analyze them.

In cosmic rays, nature grudgingly provides us with a little information about the most elementary and powerful forces of the universe. These high-powered natural projectiles tell us something about the creation and death of matter. The hope in building powerful accelerators in the laboratory is that we shall be able to produce some of nature's effects at will. I say some of them, because many of its phenomena demand energies which we cannot even dream of reproducing with our projectiles. The machines we are building at great expense are as children's toys compared with the forces that play in space.

I do not believe that experimental work alone will add much to our understanding of these forces. The history of science teaches us that great progress is usually achieved by inspired guesses, by the formulation of theories by which known facts can be explained and new ones can be predicted. A good theory is a guide through the unknown. In the case of cosmic rays, we still lack the illuminating flash of a good theory. All great theories of the past were built upon a few known facts. About cosmic rays we seem to know not too few, but too many facts. Without a theory, we cannot separate the important facts from the accidental ones.

All this suggests the difficulty of the problems with which Blackett and his group are grappling. Much of Blackett's scientific work has broad appeal not only to scientists but also to laymen. This is because he is interested in fundamental problems.

Blackett is known, among other things, as a co-discoverer of the positron. This elementary particle, equal in mass and opposite in charge to the electron, is the child of a lawful marriage between the quantum and relativity theories. The possibility of its existence was foreseen by the Cambridge physicist P. A. M. Dirac some years before it was actually observed. It was discovered in 1933 almost simultaneously and independently by Carl D. Anderson at the California Institute of Technology, by J. C. Street and E. C. Stevenson at Harvard University, by Blackett and G. P. S. Occhialini at Cambridge University, and by Frédéric and Irène Joliot-Curie in Paris.

During the last three years Blackett has been working on another project which has evoked general interest all over the world—a new theory about the magnetic field of the earth. Blackett's theory (or, rather, guess) is rejected by many physicists; I must admit that I belong to the nonbelievers. If it should turn out to be correct, however, it will be one of the most fundamental discoveries of this century.

No one has ever suggested a satisfactory theory to explain the earth's magnetism. Blackett's idea is that it is due to the earth's rotation. He holds that all bodies of matter produce a magnetic field when they rotate. It has been shown, of course, that a spinning particle in an atom has a "magnetic moment." Blackett has written an equation which states that the poles of the magnetic field of a massive rotating body must lie on the axis of rotation. (This is almost so in the case of the earth, but the geographic and magnetic poles do not quite coincide.) His equation also declares that the "magnetic moment" characterizing the magnetic field is proportional to the "angular moment" characterizing the rotation of the body. Just why rotational energy is connected with magnetic force is not, however, explained. Blackett writes: "An explanation of this phenomenon must be sought in a new fundamental property of matter not contained in the structure of present-day physical theory."

The physicists' skepticism of Blackett's theory derives in part from the fact that the experimental evidence he himself cites leaves some doubt as to the general validity of his equation. Harold D. Babcock's beautiful experimental work at Mount Wilson Observatory shows that there are stars with a periodically changing magnetic field. The axis connecting the magnetic poles seems to change, whereas the axis around which the star rotates apparently does not change, which contradicts Blackett's view that the two axes must coincide. Moreover, the U. S. physicist Walter Elsasser and the British geophysicist Edward C. Bullard have recently suggested theories which indicate at least the possibility of another explanation of terrestrial magnetism that would be consistent with the known laws of physics.

Blackett's theory might be tested by a crucial experiment which in principle would be very simple—construct a mas-

sive sphere and then cause it to rotate As it begins to rotate, a magnetic field should appear For both technical and theoretical reasons, however, such an experiment would be very difficult to perform If it should prove to be feasible, then Blackett, with his great skill in precision experiments, is the man to do it. He has found the problem of the earth's magnetism altogether fascinating, and he has already done some experimental work at Manchester on certain aspects of it, such as the measurement of the variation of the earth's magnetic field with depth

There are other universities in Great Britain where important work is going on in physics—Bristol, Liverpool, Edinburgh, Cambridge, Oxford. With remarkable devotion to the long view, the British Government has not extended its austerity program to science It has provided adequate means for research and recently raised the salaries of university personnel. I found an equal appreciation of science in Ireland and Poland, the other European countries that I visited.

When I arrived in London from Manchester to fly home, I found that I had made a mistake; my plane was not to take off until the next day. I used the extra day of grace to drive down to Cambridge, where I had once spent two thrilling years. I still think Cambridge is the most wonderful place in the world Though England has changed, looks shabby, poor and depressed, Cambridge remains the same glorious town. The colleges, Trinity College court, the bridges, the willow trees bending over the narrow river—all these appear as beautiful as ever. Even the people seem the same. Though faces have changed, the newcomers talk and behave according to eternal Cantabrigian rules.

True enough, the Cavendish Laboratory is not precisely as it was 15 years ago. Cavendish then seemed the center of the universe. It was the golden flower of the golden age of physics in England. There in one lecture room one could meet Lord Rutherford, J. J Thomson, Francis W. Aston, Charles T. R. Wilson, J. D. Cockcroft, Peter Kapitza, Max Born, R. H. Fowler, Blackett, Chadwick, Dirac, Oliphant and others whose names will long endure in the history of physics. Some are dead; others have moved to other universities to become leaders of their own schools of research. Yet even these great changes seem but small fluctuations on the Olympian face of this imperishable institution. It is good to know that in this changing world there is an invariant point—Cambridge.

Leopold Infeld is professor of applied mathematics at the University of Toronto and author, with Albert Einstein, of The Evolution of Physics.

RUDOLF E. PEIERLS, mathematical physicist at the University of Birmingham, has also taught at University of Manchester. He is German-born.

MARCUS L. E. OLIPHANT, physicist at University of Birmingham, supervises building of Birmingham's proton synchrotron, or "White Oliphant."

Fluorocarbons

The marriage of carbon and the reactive gas fluorine has resulted in a whole new family of stable and promising compounds

by J. H. Simons

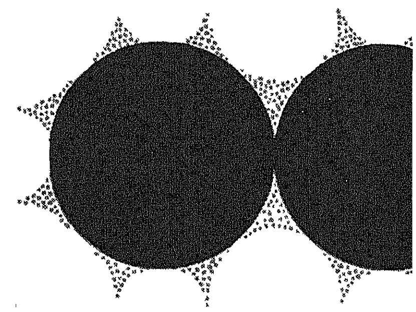
THE word fluorocarbons, which made a quiet entrance into the vocabulary of science about a decade ago, has recently been receiving more lively attention, and it appears that the frequency of its use will increase rapidly in the near future. It is the name for an entirely new domain of chemistry. It stands not merely for a new kind of laboratory curiosity but for millions of new substances, many of great utilitarian value. These substances are not found in nature, they are in the fullest sense a creation of modern chemical technology. Unknown to the ancients and unobtainable from nature's storehouses, the fluorocarbons appear to be something new under the sun.

The fluorocarbons are chemical brothers of the hydrocarbons, the immensely important class of substances that fuels our civilization. The hydrocarbons are compounds of carbon and hydrogen, the fluorocarbons, of carbon and fluorine. The fluorocarbon molecules in general have the same architecture as the corresponding hydrocarbons, the only difference being that fluorine atoms instead of hydrogen atoms are used in their construction. Thus the fluorocarbons have some superficial resemblances to the hydrocarbons. There the similarity ends In reactivity, stability and many other fundamental chemical properties the two classes of substances are vastly different.

Let us consider briefly how the contrasting properties of hydrogen and fluorine account for these differences. All chemical elements are divided roughly into two general classes. 1) those that readily react with oxygen, or react with acids to produce hydrogen, and 2) those that readily react with hydrogen. Hydrogen and carbon belong to the first class, they burn, or react with oxygen, quite readily, the former forming water and the latter carbon dioxide. This class of elements is called electropositive. The element fluorine, on the other hand, belongs to the second class, called electronegative; it reacts very readily with hydrogen. (Other typical elements in this class are oxygen and chlorine.) Fluorine is the most electronegative substance known, and the most chemically reactive gas. It sets fire to wood, paper, cloth and other similar materials at room temperature. It even reacts with water, and without much provocation will set fire to most of the metals. It reacts with glass, porcelain and most rocks. A yellow-greenish gas with a rather pungent odor, it is dangerous to touch or inhale.

Obviously the combinations of hydrogen and of fluorine with carbon must result in substances of vastly different nature. We would expect hydrogen and carbon, two electropositive elements, to form a highly combustible product, and of course they do. In the combination of extremely electronegative fluorine with electropositive carbon we may be uncertain what to expect At first thought one might suppose that the fluorine compound would be highly reactive Actually fluorine and carbon form a durable attachment which strongly resists disruption. We might liken them to the opposite sexes the two opposite substances have a strong chemical affinity for each other, and when their mutual affinities are satisfied by combination, there is little affinity left over with which to engage in further combination. So both carbon and fluorine, when joined in a fluorocarbon, show little tendency to react with other substances.

How do the fluorocarbons behave as a combination? We can best approach this question by considering the behavior of the familiar substances on which they are modeled—the hydrocarbons The latter form much of the stuff of our everyday experience—gasoline, coal, lubricating oil, rubber, moth balls, to mention only a few. Combined with other elements, such as oxygen, sulfur and nitrogen, they form the host of substances known as organic compounds. These range from relatively simple molecules like alcohol, ether and acetic acid to wood, paper, wool, silk, cotton, nylon, dyestuff, paint, all of our foods and practically all of our medicines. It was once thought that organic substances could be produced only by living organisms, but chemical technology has manufactured many organic materials that no living organism would recognize as its product.

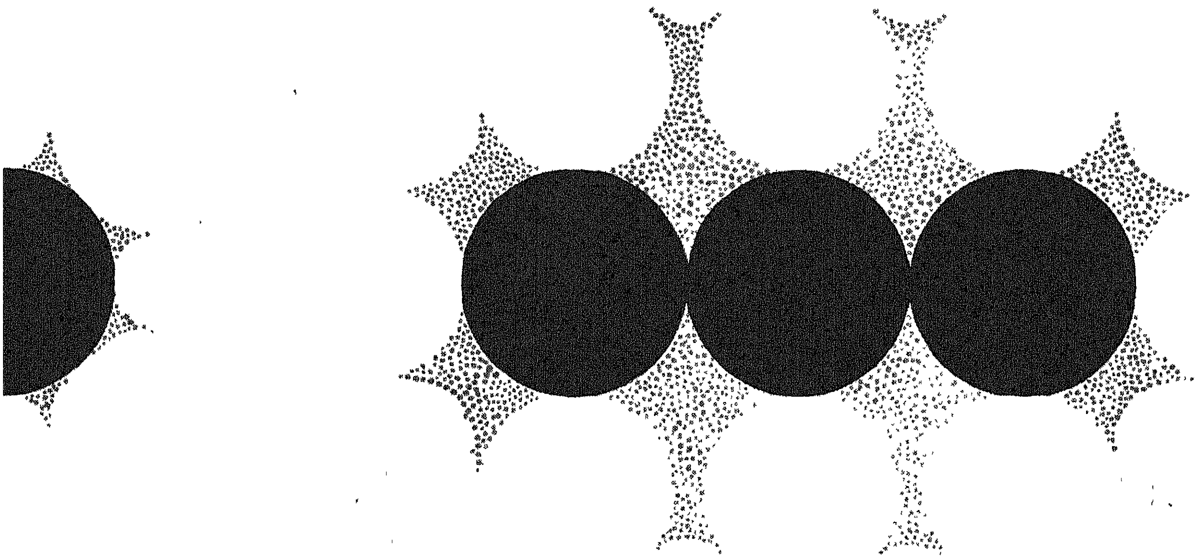


MOLECULES of a hydrocarbon (*at left*) and a fluorocarbon (*at right*) indicate why the fluorocarbons resist

We note at once that the hydrocarbons and their derivatives are used almost exclusively for two purposes. 1) fuel, which includes food, and 2) construction material. The first use depends on the combustibility of the compounds, the second on the structural properties of the element carbon. Unfortunately combustibility, either rapidly in fires or slowly in the form of deterioration and decay, is not a desirable property in construction materials. It is in this class of uses that the fluorocarbons are going to be of great value. They are ideal materials of construction, for they combine the structural characteristics of carbon with the advantage of an extreme chemical inertness.

Fluorocarbons do not burn, corrode, mold or decay. Neither rodents nor insects nor fungi can find any nourishment in them. They may be used to make paints, lubricants, plastics, rubber, cloth fibers, oils and solvents that defy fire and attack by organisms. The furniture, draperies and other decorations that make even a "fireproof" house or hotel a blazing stove when fire gets under way can be as noncombustible as the exterior when they are made of fluorocarbons.

Future fluorocarbon products may similarly improve your automobile. When proper fluids are prepared, it will have a sealed engine with fluorocarbon lubricants that need no replacement. The



combining with other substances. In these highly schematic drawings the carbon atoms are black. Surrounding them at left are hydrogen atoms, the covalent radii of which are .32 Angstroms. Surrounding them at right are fluorine atoms, radii of which are .64 A. Larger fluorine atoms shield internal force field of the fluorocarbon.

liquid in the cooling system will also be a fluorocarbon; no antifreeze will be necessary, and the radiator will never rust. The tires will last for the life of the car. They will be made of fluorocarbon elastomer which will not undergo the deterioration of slow oxidation. The cloth of the seat covers will be fire-repelling and dirt-repelling. It will be made brilliant with light, fast colors, given permanence by fluorocarbon radicals in the molecules of the dyes. The upholstery will be protected against fire by means of fluorocarbon compounds. If the car should somehow still catch fire, the radiator liquid will be available as a fire extinguisher. Even the motor may undergo drastic changes one can imagine the internal combustion engine replaced by a high-temperature turbine impelled by a dense stream of thermally stable fluorocarbon vapor.

THESE are but a few of the possibilities inherent in this new class of materials. The fluorocarbons and their derivatives will be a branch of chemistry even larger than the hydrocarbons. The fluorocarbon domain should not, however, be confused with organic chemistry. Its chemical properties, methods of synthesis and other important characteristics are entirely different. Fluorocarbon oxides, nitrides, bromides, iodides and other derivatives have properties altogether unlike the analogous organic compounds. For one example, hydrocarbon peroxides are dangerously explosive, but fluorocarbon peroxides are not.

Nevertheless the architecture of the fluorocarbon molecules so closely parallels that of organic compounds that it is convenient to employ as much of the well-established system of terminology for naming the compounds as is possible. To distinguish the fluorocarbons from organic chemicals we simply insert the syllable "for" before the ending of the organic name. For example, the fluorocarbon counterpart of the hydrocarbon methane (CH_4) is called methforane (CF_4). Other typical fluorocarbon compounds are. ethforene, C_2F_4; ethforane, C_2F_6; octforane, C_8F_{18}; methforyl oxide, $(CF_3)_2O$, methforyl peroxide, $(CF_3)_2$-O_2, fluoroxymethforane, CF_3OF; methforyl nitrogen difluoride, CF_3NF_2, bromopropforane, C_3F_7Br; butyrforic acid, $C_3F_7CO_2H$; methforylcyclohexforane, $CF_3C_6F_{11}$.

As we have noted, in some physical properties the fluorocarbons are very similar to the analogous hydrocarbons, in others, very different. For example, the comparable compounds in both groups generally have roughly similar boiling and freezing points. On the other hand, they differ radically in surface tension. The fluorocarbons have much lower surface tension, the lowest, in fact, of any class of substances.

By way of illustration, let us compare a parallel pair of compounds—the hydrocarbon pentane (C_5H_{12}), found in petroleum, and the fluorocarbon pentforane (C_5F_{12}). Both have the same number of atoms and the same carbon skeleton structure. Both are clearly transparent mobile liquids that boil at practically the same temperature, slightly above that of the ordinary room. Both freeze at approximately 200 degrees below zero Fahrenheit. They have approximately the same viscosity, and about the same amount of heat is required to transform an equal number of molecules from the liquid to the gaseous state. Both are insoluble in water, and neither will conduct an electric current.

Notwithstanding all these similarities, one compound can easily be distinguished from the other. The pentforane molecule weighs nearly four times as much as the pentane. The surface tension of pentforane is more than 30 per cent less than that of pentane. If two vials, one containing pentforane and the other an equal volume of pentane, were placed side by side, there would be several ways of distinguishing them without even opening the vials. In the first place, the fluorocarbon would be much heavier. In the second place, the pentane, due to its surface tension, would have an appreciable meniscus, or curve, on its surface where it touched the glass, while the surface of the pentforane would appear flat almost to the very edge. On opening the vials you would immediately smell the difference: pentane has a significant odor, whereas pentforane is practically odorless. The pentane would catch fire readily and burn with a yellow and very sooty flame. The pentforane would refuse to burn; it could, in fact, be used as a fire extinguisher.

IN their chemical and thermal stability the fluorocarbons are unique. Powerful chemical reagents, such as acids and bases, oxidizing and reducing agents, are without effect on them. What are the reasons for this tremendous resistance to chemical attack? To begin with, the underlying carbon skeleton is itself very resistant, as is apparent in carbon's most

compact form, the durable diamond. But obviously the carbon skeleton cannot account for the great difference in durability between the fluorocarbons and the hydrocarbons. The difference must derive from the differing sheaths of atoms surrounding the skeleton. Part of the explanation lies in the contrasting energy situations in the two types of combination. The decomposition of a fluorocarbon, or separation of fluorine from carbon, requires a considerable amount of energy, whereas when a hydrocarbon decomposes it liberates energy. In other words, it takes a great deal more energy to decompose a fluorocarbon than a hydrocarbon. Another reason for the difference in stability is that hydrogen atoms have a great tendency to react or combine with oxygen or oxidizing agents, while fluorine atoms resist this type of reaction, particularly when they are combined with elements such as carbon.

These explanations, however, only partly account for the refractory nature of the fluorocarbons. To explain it fully we must also examine the mechanism by which a chemical reaction starts The exact point of attack upon a molecule by a reacting substance is probably not at one of the atoms of the molecule but rather at the force field that lies between the atoms. Because hydrogen atoms are very small, the hydrogen-atom envelope of a hydrocarbon molecule does not shield the internal force field. On the other hand the larger fluorine atoms that envelop a fluorocarbon molecule apparently form a very effective shield against attack by an intruding molecule. Moreover, as we have seen, the fluorine atoms, when married to carbon, show little tendency to combine further with other elements or to desert carbon for another partner. Thus the fluorine-atom envelope not only protects the carbon skeleton but is itself resistant to attack. The heart of diamond is sheathed in the skin of an alligator.

The fluorine sheath covering the carbon skeleton is so highly satisfied with its partnership that it retains little attractive force even for substances of like kind. This is, of course, the reason for its low surface tension, since surface tension is a manifestation of the attraction between molecules in a liquid. And because fluorocarbons show even less attraction for unlike substances than for their own kind, the fluorocarbon solid plastics made so far have defied all attempts to find adhesives that will stick to them. Even the baker's tacky dough does not adhere, so fluorocarbon plastic makes an ideal coating for dough boards, for which it is already in use. Such boards do not require flouring to prevent sticking. It is this property that leads to the expectation that articles made of fluorocarbons will be easy to clean.

The great stability of the fluorocarbons will eventually make it possible to synthesize even more compounds in the fluorocarbon domain than in the domain of organic chemistry. Since chemists can now envision about one million possible organic compounds, we can conservatively estimate that there will be at least that number of fluorocarbons. Moreover, molecules which are part fluorocarbon and part organic can be constructed, so the foreseeable compounds of the two combined systems number a million times a million. Considering that most commercial substances are combinations or mixtures of compounds, the number of possible useful materials from this array of molecules is practically limitless—many times a million million.

WHY are the fluorocarbons such a late arrival on the chemical scene? The answer is easy: the production of fluorocarbons requires techniques entirely different from those used in other branches of chemistry, and these techniques have only recently been discovered Early experimenters tried to make carbon-fluorine compounds by reacting carbon with gaseous fluorine, just as carbon oxides are made by the reaction of carbon and oxygen. But almost the only product they were able to obtain was methforane, and the experiments generally ended in explosions. A little more than a dozen years ago workers in the Fluorine Laboratories at The Pennsylvania State College found that the reaction could be controlled by means of suitable catalysts. With this knowledge they soon produced a large number of interesting new substances. These, naturally, were named fluorocarbons.

The State College discovery turned out to be extremely opportune. Soon after the atomic bomb project started early in World War II, chemists working on the production of fissionable material found that they needed a substance that could be mixed with uranium hexafluoride without reacting with it. The first specifications called for a material that was very stable and possessed a boiling point and a molecular weight not too far away from those of uranium hexafluoride Only a fluorocarbon would meet these requirements Fortunately two cubic centimeters of a fluorocarbon in the right boiling range had been separated from the original preparations in the Fluorine Laboratories. The major constituent of this sample was heptforane. The sample was supplied for tests in 1941. The atomic bomb workers found that it resisted the attack of the reactive uranium hexafluoride, and so the newborn fluorocarbons were baptized as a military material. For reasons of military security they were designated as "Joe's Stuff."

Although the compounds first supplied met the initial specifications, chemists, like other people, are never satisfied with what they have. They always demand more and better substances. Fluorocarbons with physical properties different from the original sample were soon desired for lubricants, elastomers, gasket materials, valve packings and so on, especially for the gaseous diffusion plant at Oak Ridge, which cycled uranium hexafluoride through barriers and pipes to separate U-235 Research teams throughout the country were started on the difficult task of making these compounds. That they succeeded is now known in the chemical profession, and tangibly attested by the existence of the Oak Ridge plant.

Much technical knowledge was gained in the course of this work, but most of the fluorocarbon processes used during the war are too costly and difficult for commercial peacetime use The usefulness of the fluorocarbons was demonstrated, but their cost was so high as to discourage any consideration of them for ordinary applications. We had realized in the Fluorine Laboratories even before the military uses of Joe's Stuff were known that methods other than the original catalytic reaction between the elements would be necessary to produce fluorocarbons on a commercial scale. The catalytic process, although it has been improved and will probably be commercially useful for some products, has an important shortcoming. it produces a mixture of many fluorocarbons instead of just the one desired. Some research was done before the war on a superior method of production—the electrochemical process This fundamental work was halted by the war, but it was resumed immediately afterward and the process was perfected.

This process produces fluorocarbons at low temperatures and without the necessity of using fluorine in its elemental form. The product is obtained in one step from available and inexpensive raw materials. The raw materials are hydrogen fluoride and organic chemicals.

The heart of the apparatus is an electrochemical cell consisting of an iron container in which is suspended an electrode pack. This is made up of thin sheets of nickel suspended vertically parallel to one another and separated by a small fraction of an inch. Alternate sheets electrically connected form the anode and the cathode, much like the plates in a storage battery. Through a system of pipes the raw-material mixture of hydrogen fluoride and organic chemical is fed into the cell. Somehow the flow of electricity causes the fluorine in the fluoride to replace the hydrogen in the organic material, forming a fluorocarbon, with the freed hydrogen from both the hydrogen fluoride and the organic compound escaping as a gas.

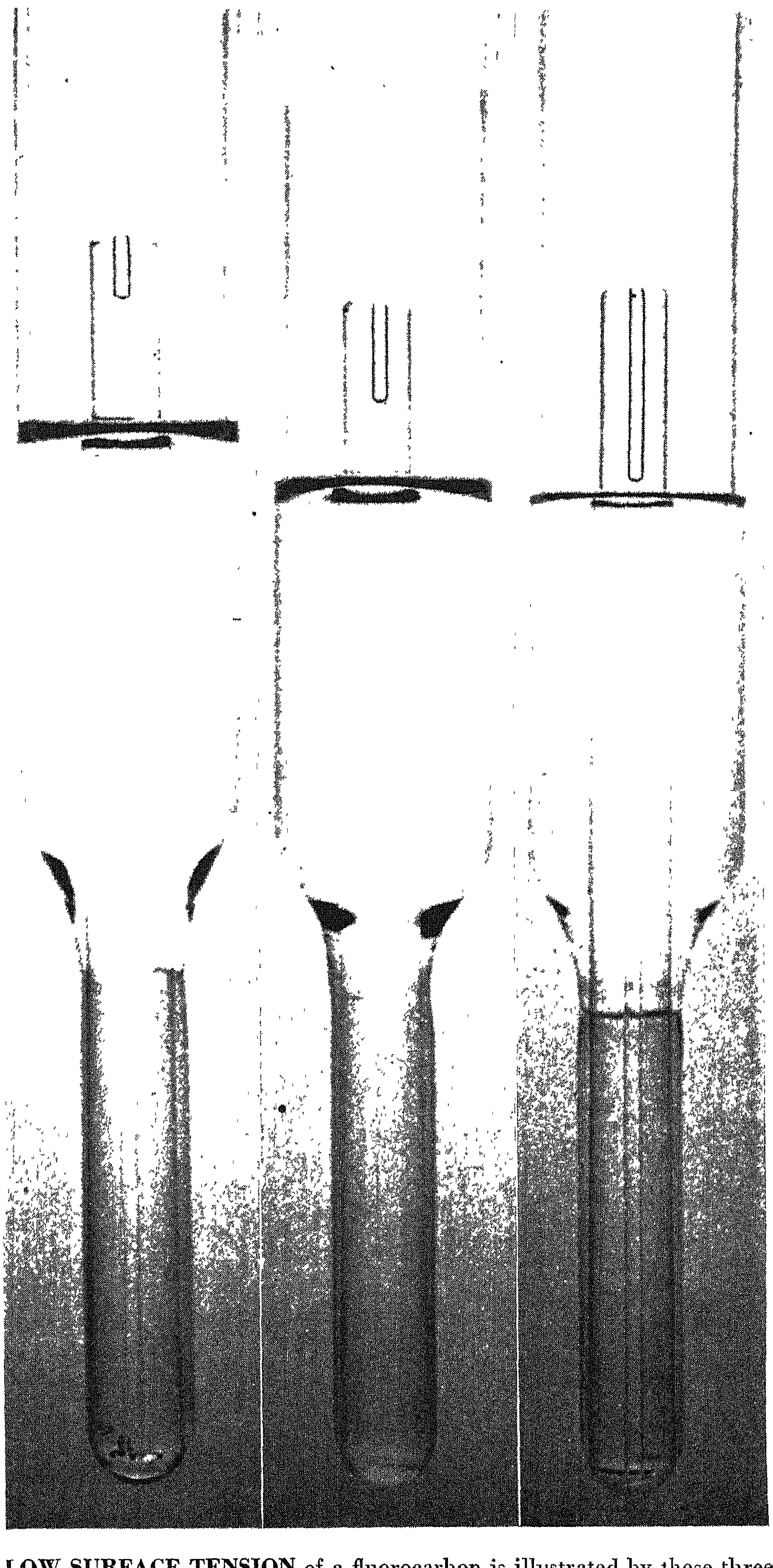
Just how and why this process works is still a mystery, but the important thing is that it does work, and in a highly efficient manner. The electrode pack

apparently lasts almost indefinitely. A cubic foot of the pack produces some 25 to 50 pounds of fluorocarbons per day, depending upon conditions. The cost of production is much less than by other processes, and by use of the proper raw materials many of the fluorocarbon derivatives can be obtained in one step and in good yield. A pilot plant employing this electrochemical process has been in operation in St. Paul, Minn., for several years—long enough to demonstrate the feasibility of the process for large-scale production. This is highly encouraging; it would be sad to whet man's appetite for a host of desirable products and then be unable to produce them.

THERE is no question of the abundance of the raw materials. Carbon, as everyone knows, is sufficiently plentiful. And fluorine, according to all estimates, is roughly as abundant as carbon. Fluorine-containing minerals are widely scattered over the earth's surface; they are found in practically every state of the Union and practically every country. The major ore at present is fluorspar or calcium fluoride, of which there are many small or impure deposits. One of the largest and best deposits is on the Illinois-Kentucky border. Another mineral containing considerable fluorine is the aluminum ore cryolite, chemically identified as sodium aluminum fluoride. Smaller proportions of fluorine are found in many other minerals. One is the phosphate called apatite, which often contains from three to five per cent fluorine. This material is mined chiefly for phosphorus for fertilizer, and the fluorine in it at present is almost entirely discarded; in fact, some of it escapes from the furnaces in the form of noxious compounds that devastate the landscape. In Florida, the principal apatite-mining area, approximately a million pounds of fluorine is removed from the ground every day, and most of it is used. We may note in passing, for the edification of those who may be interested in the mystic significance of words, that in the U. S. the largest reserve of fluorine is in Florida, and in Europe the deposits of apatite lie in Hungary.

Whether or not high-grade ore of one chemical formula is available in sufficiently large deposits is a matter for the experts to argue. The layman can be confident that if there is an ample supply of fluorine on the earth's surface, technology will find a way to make it available for use; and the one big predictable use for the element will be the fluorocarbons and their derivatives.

J. H. Simons is professor of physical chemistry and director of the Fluorine Laboratories at The Pennsylvania State College.



LOW SURFACE TENSION of a fluorocarbon is illustrated by these three photographs. Vessel at left contains water; vessel in center, a hydrocarbon; vessel at right, a fluorocarbon. Inside each vessel is a capillary tube in which liquids rise according to their surface tension. Water rises highest; the hydrocarbon rises less; the fluorocarbon rises almost not at all.

DEMOCRITUS ON THE ATOM

The remarkable insights of the Greek materialist philosopher are preserved in the writings of later commentators

DEMOCRITUS is depicted as a sad old man in an 18th-century engraving. Most earlier representations showed him laughing. According to the second-century Bithynian astronomer Hipparchus, Democritus lived to be 109.

DEMOCRITUS, the greatest of the Greek materialist philosophers, was born in the Thracian town of Abdera early in the fifth century B.C. He was the son of a rich man, and he spent his patrimony traveling in the East. His principal contribution to philosophy was his development of the concept of the atom, first proposed by Leucippus. He is said to have written 72 books, but none survives. All that we know of him is in the words of later philosophers, who often admired him but usually disagreed with him. A few excerpts from their descriptions of his philosophy are given here. They are reprinted from *Selections from Early Greek Philosophy* (third edition, 1947), by Milton C. Nahm, with the kind permission of Appleton-Century-Crofts, Inc.

Simplicius

"A few notes from Aristotle's *On Democritus* will clarify the thought of these men. 'Democritus considers the eternal objects to be small substances infinite in number. For these he posits a place infinite in magnitude, and he calls place by such names as void, nothing, and infinite, but each of the substances he calls, something, solid, and existent. He thinks the substances are so small that we cannot perceive them, yet they have all sorts of forms and shapes, and differences in size. Accordingly from these as from elements he generates and combines visible objects and perceptible masses. And they are disturbed and move in the void because of their dissimilarity and the other differences mentioned, and as they move they collide and become entangled in such a fashion as to be near to and touch each other. However this does not in truth give rise to any one single nature, for it is altogether silly that two or more things may ever become one. The coherence up to a certain point of substances he explains by the gripping and intermingling of the bodies, for some of them are scalene in shape, some are barbed, some concave, some convex and others have countless other differences. Accordingly he thinks they cling to each other and cohere until some stronger necessity from the surroundings approaches, shakes and scatters them.' And he speaks of genesis and its contrary, separation, not only with reference to animals, but to plants, and worlds, and, in general, all sensible bodies. If, therefore, genesis is the commingling of atoms, and destruction is their separation, then according to Democritus genesis is also the same as qualitative change." (From *de caelo*.)

"Democritus the Abderite posited as principles the full and the void, of which he called the first Being and the second Non-being. For positing the atoms as the material of things, they produce the

other things by their differences And these are three, proportion, impulsion, and arrangement, which is the same as saying shape, position, and order. For the like is naturally set in motion by the like, and the homogeneous is drawn together, and each of the shapes when it is arranged into a different combination produces another design Consequently, since the elements are infinite, they could reasonably promise to render an account of all qualities and things, an account both of the cause and the process of anything's generation." (From *Commentary on the Physics*)

"Democritus' followers assert that all the atoms are homogeneous and have weight, but because some are heavier, the lighter ones are thrust aside by the others as they fall and are carried upwards, and thus it is they say, that some things are considered light and some heavy. The Democritean group thinks that all things have weight, but since fire has less weight and is squeezed out by the things ahead of it, it is carried upward, and for this reason it appears light. And they consider that only what is heavy exists, and it is always in motion toward the center. The atoms necessarily have equal speeds when they move through the void which offers no resistance For neither will the [large and] heavy atoms move more quickly than the small and light, when nothing obstructs them, nor will the small atoms, all of which have commensurate passageways, move more slowly than the large ones when nothing resists them either." (From *de caelo.*)

Alexander of Aphrodisias

"Democritus, therefore, considering that [chemical] 'mixture' so-called occurs by the juxtaposition of bodies, which are divided into minute particles and produce the mixture by the positions of the particles alongside of each other, asserts that in truth things are not mixed even in the beginning, but the apparent mixture is a juxtaposition of bodies in minute particles, preserving the proper nature of each, which they had before the mixing. They seem to be mixed because on account of the smallness of the juxtaposed particles our senses cannot perceive any one of them by itself." (From *Meteorology.*)

Plutarch

"For what does Democritus say? Substances infinite in number, indivisible, and different from each other, without qualities and unchanging, are scattered about and move in the void. When they approach each other or collide or become entangled, some of these aggregations form water, some fire, some plants, and some men. But all things are really atoms or forms as he calls them, and besides these nothing exists. For there is no generation from non-being nor can there be any generation from things which exist because the atoms on account of their solidity neither change nor suffer any impression." (From *Lives*)

Galen

" 'For by convention color exists, by convention bitter, by convention sweet, but in reality atoms and void,' says Democritus, believing that from the conjunction of atoms all sensible qualities come into being for us who perceive them, but by nature nothing is white, black, yellow, red, bitter, or sweet, for the phrase 'by convention' means the same thing as 'by custom,' and 'for us,' not according to the nature of the things themselves, which he calls 'in reality' coining the term from 'real' which means true. And the complete sense of his argument would be as follows Men think that there is such a thing as white, black, sweet, or bitter, but in truth the universe is composed of 'thing' and 'nothing' " (From *History of Philosophy*)

Theophrastus

"Democritus in assigning a shape to each quality made sweet to consist of fairly large, spherical atoms. To the quality sour he assigned very large, rough shapes with many angles and no curves. The sharp [in taste], as its name implies, he regarded as consisting of atoms sharp in mass, angular, crooked, thin, and unrounded. The pungent needs atoms which are thin, angular, and bent, but rounded also. Salt is angular, fairly large, twisted, although symmetrical. Bitter is rounded and smooth, unsymmetrical, and small in size." (From *de causis plantarum.*)

Aetius

"Democritus held that thunder is produced by an unstable mixture forcing the cloud enclosing it to move downward. Lightning is a clashing together of clouds by which the fire-producing atoms rubbing against each other are assembled through the porous mass into one place and pass out. And the thunderbolt occurs when the motion is forced by the very pure, very fine, very uniform and 'closely-packed' fire-producing atoms, as he himself calls them." (From *Placita Philosophorum.*)

"According to Democritus, a kind of shadow [is] cast by the high parts on [the moon], for it has hollows and glens " (From *Placita Philosophorum.*)

"Democritus says that the air, too, is broken into bodies of similar shapes and rolls about with the fragments of the sound." (From *Placita Philosophorum*)

"Color does not exist by nature. For the elements have no qualities, neither the solids nor the void. What is composed of these, however, is colored by arrangement, proportion, and impulsion, that is, order, shape, and position, for appearances arise from these. Of these colors . . . there are four types, white, black, red, and yellow" (From *Placita Philosophorum.*)

Censorinus

"Democritus the Abderite believed the first men were begotten of water and slime." (From *de die natali*)

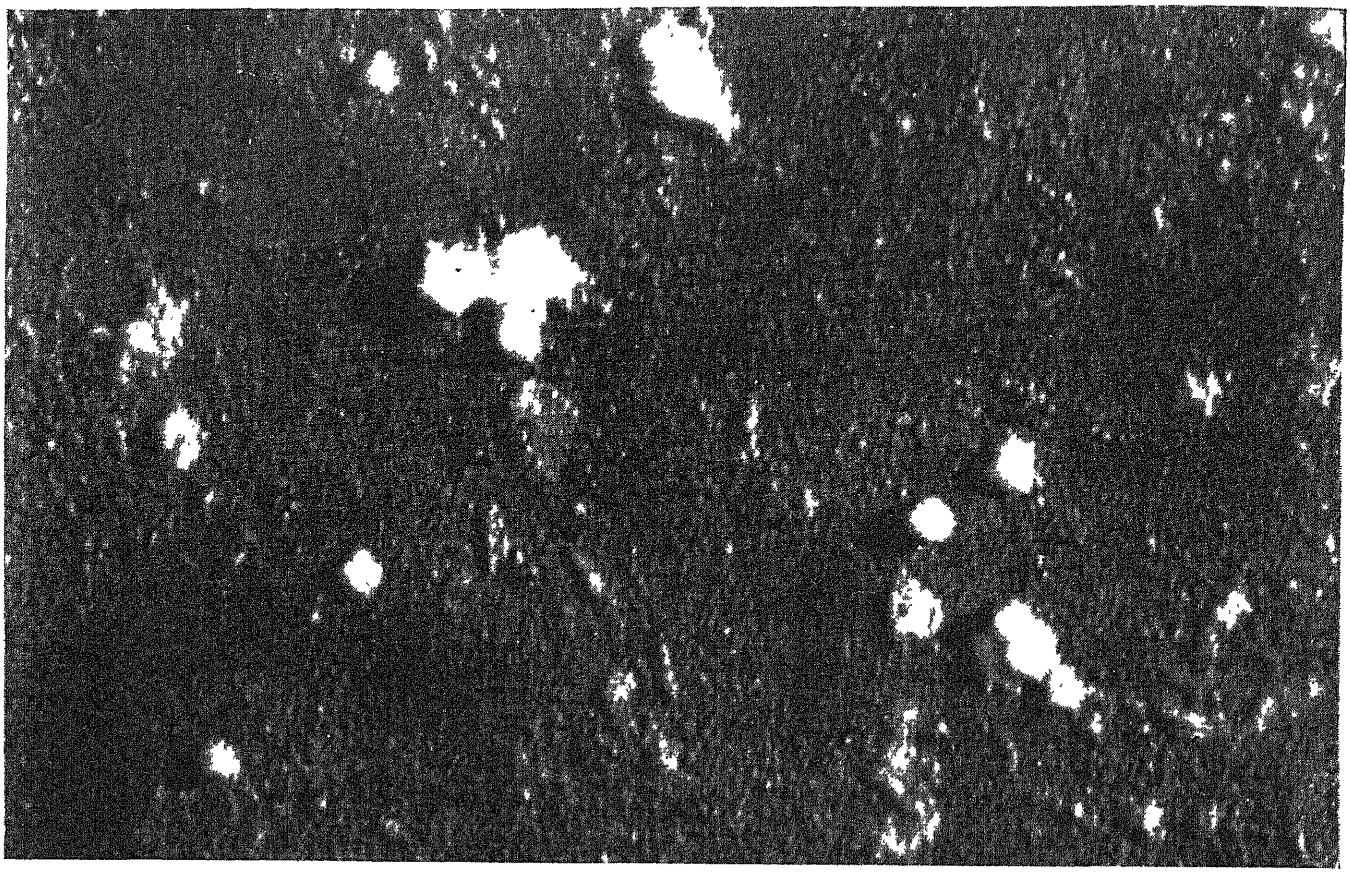
Hippolytus

"And [Democritus] would say that the realities were always moving in the void; and there are an infinite number of worlds differing in size; in some there is neither sun nor moon, in others they are larger than ours, and in others there are many suns and moons. The distances between the worlds is unequal and in some quarters there are more worlds, in others fewer, and some are growing and others have reached their full size, and others are disintegrating, and in some quarters worlds are coming into being and in others they are ceasing to exist They are destroyed by colliding with each other. And some worlds are devoid of living beings and all moisture. In our system the earth came into being before the stars, and the moon is nearest the earth, and then the sun, and then the fixed stars. The planets are not equally distant from the earth." (From *refutatio omnium haeresium.*)

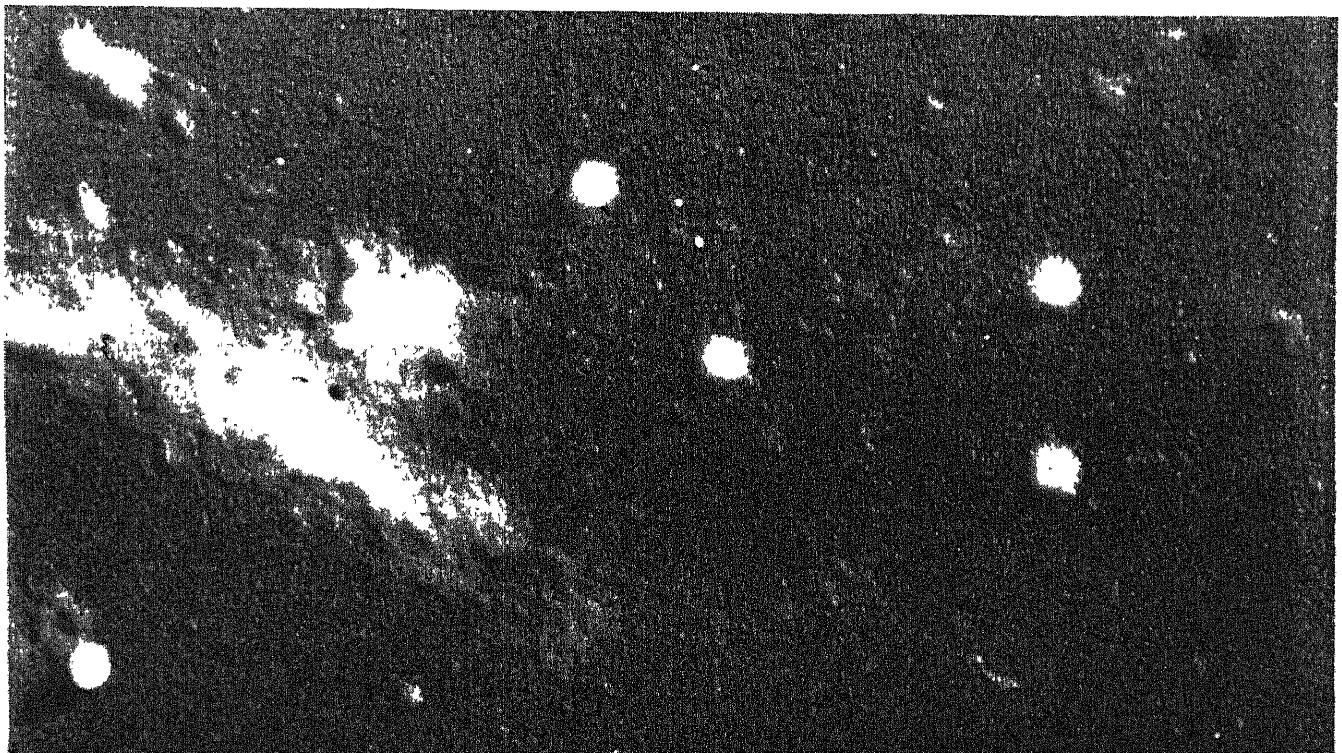
Aristotle

"Anaxagoras and Democritus say the Milky Way is the light of certain stars. For the sun at night goes under the earth. Hence those stars above the earth which the sun illumines cannot make their own light visible because it is obscured by the rays of the sun; but those which the shadow of the earth darkens so that they are not illumined by the light of the sun, do show their own light and this is the Milky Way. [The Milky Way is] the combined brilliance of many small stars in juxtaposition uniting their light." (From *Meteorologia.*)

"Democritus of Abdera holds that the distinction between male and female takes place in the womb, not however as the result of heat and cold, but it depends on which parent furnishes the dominant seed, or more exactly that 'chromosome' which originates in the organs which differentiate male from female." (From *de generatione animalium.*)



HERPES VIRUS FROM EGG is resolved into tiny spheres by the electron microscope. The spheres are each approximately 1,500 Angstroms in diameter. The micrograph specimen has been shadowed with gold to make them visible in three dimensions. The original micrograph magnified the virus material 13,000 diameters.



HERPES VIRUS FROM BODY is resolved into same spheres. Original micrograph magnified the virus 13,000 diameters. It and micrograph above were made by Geoffrey W. Rake of The Squibb Institute for Medical Research, and Harvey Blank, Lewis L. Coriell and T. F. McNair Scott of The Children's Hospital of Philadelphia.

NATURAL HISTORY OF A VIRUS

Virologists have pursued the organism that causes herpes simplex, the common fever blister or cold sore, by the subtle track it leaves within its host

by Philip and Emily Morrison

IN the 19th century natural history meant adventure and travel to distant lands. Scientific explorers sought the secrets of birds, flowers and beasts in green jungles, on snow-topped mountains and desert islands. Charles Darwin sailed for five years on H. M. S. *Beagle* to lie on the plains of Patagonia watching the condor in flight, to find on "the lofty peaks of the Cordillera" the alpine rodent bizcacha, to measure in a New Zealand forest the trunk of the kauri pine. For Darwin the adventure did not end there, of course, as a great scientist he not only collected facts but used them to analyze the forms of life and their interrelationships, and to develop a theory.

In the 20th century natural history still means adventure, but not always travel. While men continue to pursue fauna and flora to remote parts of the world, there are many who do all their exploring within the walls of a laboratory. There they are following the tracks of strange unknown organisms every whit as fascinating as the life of Patagonia Among the microorganisms whose lives and habits have been traced with curiosity, ardor and profit during the past decade is a particularly intriguing virus, the virus of herpes simplex.

One does not need to go on a journey to look for the herpes virus; almost everyone has seen its tracks on his own body. It is the organism that causes the fever blister, or cold sore, on the lip—one of the most common afflictions of man. Only a few Eskimo tribes in arctic Greenland seem to be free of it. So the explorer who sets out in search of the herpes virus goes armed not with compass, maps and machete but with a knowledge of immunology and statistics, a hypodermic needle and an electron microscope. His terrain is the human lip, the patient laboratory rabbit and the chick egg.

The story of how the herpes virus was discovered is of interest not only for itself but also because the methods used and the results obtained in its study are basic to an understanding of the biological nature of all disease. The virus was tracked down only after a long series of investigations, principally by the Australian virologist Frank M. Burnet.

Although nearly everyone has fever blisters occasionally, the cause of this affliction had mystified physicians for many years. It does not behave at all like an infectious disease. The blisters recur throughout the lifetime of an individual, usually in exactly the same spot, they sometimes accompany colds, fevers or emotional upsets, as if they were symptoms of a more general disorder; they give no evidence of spreading by contact from one person to another. In contrast, a typical common virus disease like measles begins with considerable fever, catarrhal symptoms and spots in the mouth; a rash appears all over the body, the disease spreads very readily, so that only about one per cent of susceptible individuals fail to get it upon their first close contact with an infected person, usually it attacks an individual only once during his lifetime.

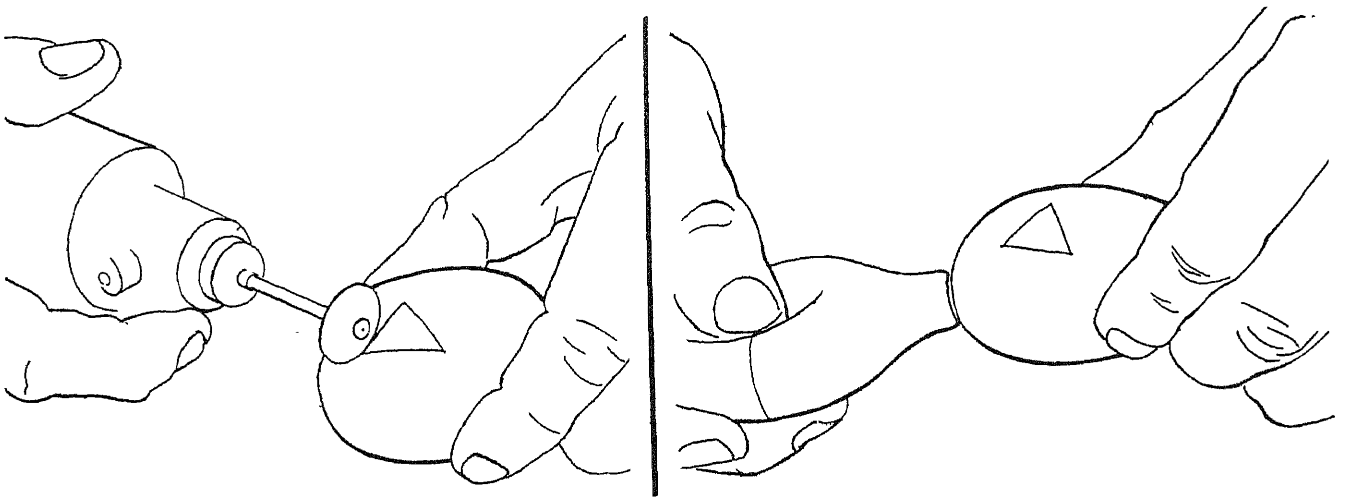
As early as 1912 some investigators discovered that a virus was present in typical herpes blisters. But this information was dismissed by most research men as not significant How could herpes be caused by a virus, they argued, when it did not conform to the pattern of other known virus infections? Nonetheless a few workers persisted in following this apparently blind alley. An encouraging but by no means conclusive experiment in 1919 showed that some of the liquid obtained from a human fever blister would produce lesions on the cornea of a rabbit. Again the evidence was rejected. A number of other theories were offered to explain the recurring blisters. One of the most widely supported was that herpes was simply a peculiar external irritation which affected certain sensitive cells

In 1939, however, the virus theory received a tremendous boost from findings by Katharine Dodd, L. M Johnston and G. J. Buddingh at the Vanderbilt University School of Medicine. They learned that an infectious organism could be recovered from the mouths of infants suffering from a common form of sore mouth known as aphthous stomatitis They did not see the typical herpes blisters on these children, nor, of course, could they see the virus itself. Their chief evidence that herpes virus was present was the fact that they found herpes antibodies in the children's blood. In other words, they detected the virus not by its usual blister track but by a kind of chemical scent The antibodies they found had previously been observed in herpes patients.

Spurred by these experiments, Dr. Burnet and other investigators undertook a long, painstaking series of measurements of herpes antibodies, hoping to prove conclusively that herpes was a virus infection and to study the virus in all its peculiar habits. In these studies they had the benefit of a great deal of knowledge about antibodies that has been developed in recent years.

Antibodies, one of man's major defenses against disease, are manufactured by the human body in a number of forms. Each variety, evoked by a particular infectious organism or other foreign agent, is a specialist it has a particular chemical structure and possesses the specific ability to neutralize the invader that evoked it. Its action on its antagonist is quantitative and measurable. When, for example, a rabbit is injected with a certain number of diphtheria bacteria mixed with a certain amount of the specific diphtheria antibody in blood serum, the animal shows no symptoms of the disease.

IN the case of herpes virus perhaps the most useful medium for this kind of measurement is the fertilized hen's egg. The living cells of the developing chick embryo provide a favorable en-



VIRUS IS CULTIVATED in fertilized eggs. Shown in these drawings is the technique used by Lederle Laboratories. At left a triangular window is cut in the egg. Next a rubber bulb is applied to a tiny hole at

vironment for growing virus. In a herpes experiment the investigator carefully removes a small portion of the shell of a fertilized egg, lifts the shell membrane, thus exposing the outer layer of the living embryo, which is filled with blood vessels, and then inoculates this layer with a certain amount of infectious liquid from a typical fever blister. On this rich field the herpes virus grows rapidly. Within two or three days the membrane shows raised white spots or plaques, which are colonies formed by enormous numbers of individual particles of virus. The investigator then repeats the procedure, but this time adds to the infectious material a measured amount of serum from the blood of an individual believed to have specific antibodies for herpes virus. By counting the difference in the number of lesions produced on the membrane before and after adding the serum, he can make an accurate estimate of the amount of antibody present in the individual who supplied the serum.

Most normal adults have antibodies against herpes. These antibodies are a very peculiar breed. Usually an individual who has antibodies against a specific infection is immune from a recurrence of that disease; a notable example is measles. But the investigators found that in the case of herpes the antibodies do not immunize the patient; he may still have repeated attacks of fever blisters. On the other hand, in spite of the wide distribution of the virus some people who have no herpes antibodies never get fever blisters. The herpes antibodies show another peculiarity. In many diseases, notably diphtheria and influenza, the production of antibodies varies with time or with the virulence of the attack. A mild infection produces a moderate concentration of antibodies; after a severe infection the convalescing patient at first has many antibodies, then the concentration diminishes and finally disappears. In herpes, however, the investigators found that it is all or none—there are either a great number of antibodies or none at all. Infants with stomatitis who had no antibodies at the time they became ill had a great many within three weeks, and continued to have them. No one who had ever had a fever blister failed to show a large number of antibodies, and a comparable concentration was found in some people who could not remember having had such blisters. People who have herpes antibodies seem to keep them in their blood for life, and even for some time after death

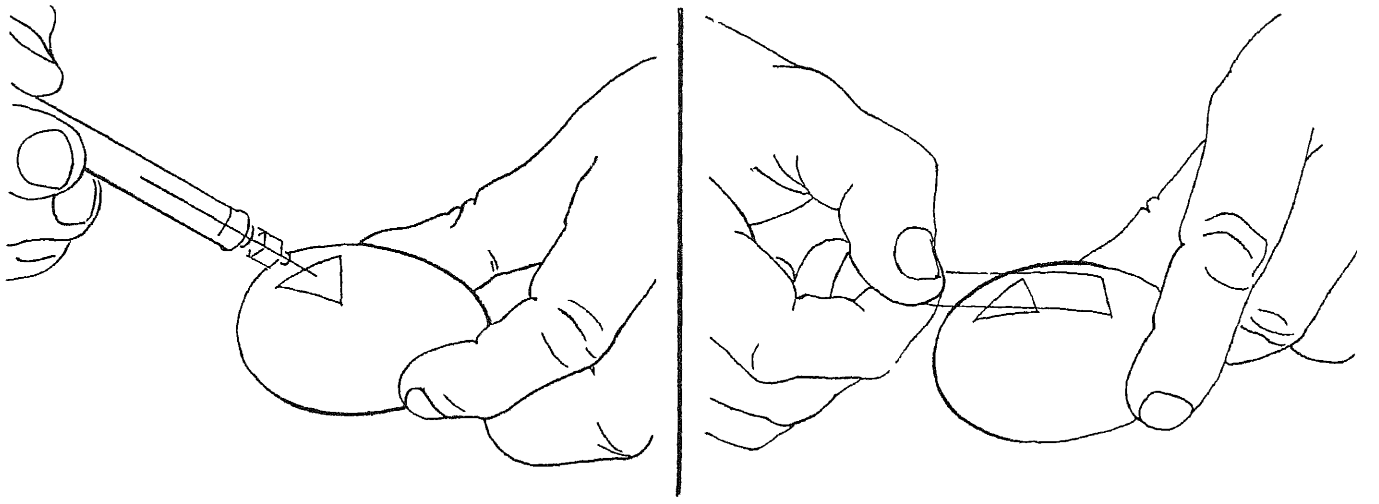
With these facts at hand, the picture of the herpes virus began to take definite shape. The investigators determined by filtration that the virus is about 1,500 Angstroms in diameter—roughly the same size as the influenza and rabies viruses. Like other viruses it is essentially a nucleoprotein. It first appears in young children, usually in the form of a mild sore mouth Once it attacks an individual, it remains with him until death, though it makes its presence known only by occasional blisters or not at all. If you escape herpes as a child, it is somewhat more difficult to acquire it as an adult, but it can be done A woman worker in Burnet's group acquired the telltale antibodies during their investigation. Upon inquiry, Burnet learned that she had become engaged to a man who had had herpes for some time, and she had evidently acquired it from him!

Infection with the herpes virus seems to vary considerably with socio-economic status, according to investigations made in Australia and England. Among university graduates, who come generally from comfortable homes, only about 37 per cent showed herpes antibody, among groups in lower income brackets, as many as 93 per cent showed antibody. This statistic has been interpreted as evidence that herpes is probably spread by close physical contact, perhaps between the mouth of the child and the saliva of the parent. The greater crowding and poorer hygiene in lower income groups would tend to help the spread. If herpes were spread by airborne droplets rather than by contact, it is difficult to see how anyone could escape, regardless of income

However that may be, the Burnet group positively identified herpes as an infectious disease, like measles, mumps or any other virus infection except for the unique fact that it persists all through life, almost without symptoms Only occasionally, when the resistance of the body is lowered by fever, a cold, or some emotional strain, do the infected cells of the lip, where the virus presumably lives, break down into the typical blisters.

So far we have been concerned with the description of herpes virus from the point of view of the explorer and the naturalist. We have identified it and studied its habits. But it is valuable also to assume the point of view of the historian and the ecologist, to trace the virus' origin and development and its relationship to other organisms. Like Darwin, the modern virologists have not stopped at description but have carried their researches into this broad and rather speculative field as well

The natural habitat of the herpes virus is man, it seems to be as much at home in man as is the mistletoe on the oak. The creature multiplies and gains its food and shelter from the human body, and from its own point of view it is extremely successful, for it invades almost every human being, is never dislodged and is spread constantly to new hosts. But an essential element of this parasite's successful adaptation to its environment is that it does not do much damage to man. This is not because the virus is totally incapable of doing damage, on the contrary, when introduced into rabbits or mice it often infects the central nervous systems of these little animals and produces a true and usually fatal encephalitis. There are a few rare cases



the end of the egg to draw down the membrane beneath the shell. Then the virus material is injected into the embryo. Finally the window is covered with transparent tape so the virus colonies may be observed.

known in which herpes virus has caused encephalitis even in human beings.

The generally harmless behavior of this creature in its natural host gives us an exceptionally illuminating insight into the survival value of a biological equilibrium. If you die of encephalitis induced by herpes virus, this is of little advantage to the virus, since it cannot spread in large numbers from the dead. On the other hand, if you carry herpes virus always with you and suffer only an occasional blister, the virus lives happily in equilibrium with you for a relatively long time and has splendid opportunities to grow and spread. Herpes virus is a concrete demonstration of a great generalization made by the late Theobald Smith of the Rockefeller Institute: wherever you find a parasite that has affected a given host over a long period of time, you will find that the infection does not interfere with the survival of the host and is of low virulence. A strange host, such as a mouse or a rabbit, cannot expect such good behavior from the human herpes virus because the host has not had time to establish the basic chemical adjustment necessary for a state of equilibrium. Just as psittacosis is much more virulent in people than in parrots, so herpes is much more virulent in the mouse than in human beings.

The history of herpes in man leads us to speculation on its sociology. We know that virulent diseases like measles and smallpox have not always been worldwide. When measles first strikes in virgin territory (*e.g.*, the Faeroe Islands) it becomes a terrible scourge; so it was with smallpox when it was introduced among the American Indians and among the Samoans. Such diseases are probably diseases of civilization—of cities or large, stable communities of men. Measles is more or less constantly present in all large communities, and there are major epidemics or sudden increases in prevalence at about three-year intervals. It spreads rapidly, but after a comparatively short illness it confers long-time immunity on those who recover. By the age of 20 approximately 85 per cent of the population in a civilized country have had the disease, and second attacks are unusual. The measles virus is able to survive indefinitely in a city because there are always new people to carry and spread it among a constant new crop of children who have no immunity. It would have a hard time surviving in an isolated family or small tribe of cave dwellers or nomads, for if the group were accidentally infected from some outside source, all of its members would be sick, the survivors would be immune and the disease would die out.

The herpes virus, on the other hand, is self-perpetuating. It is the only known virus disease in which a woman who had the disease as a child can infect her own children many years later, and they in turn infect their children. Thus the virus can be forever transmitted even within a single isolated family.

So this newly found living form, virus of herpes simplex, is not new at all but probably older than the pyramids or the ancient plagues, older than writing or even fire. It is undoubtedly one of the oldest domesticated organisms we know, older even than man's friend the dog. The occasional colony of herpes on your lip is the evidence of a slight disturbance of the nice balance between 10,000 generations of men and countless generations of these little globes of nucleoprotein 1,500 Angstroms in diameter. Only as a result of many mutations and selective adaptations could the herpes virus have achieved so successful and peaceable a relationship and struck so delicate a balance between its own aggressive tendencies and the defensive mechanisms of its human host.

THE human race exists in a rather sensitive and unstable relationship with its environment; it can be profoundly disturbed by slight changes in the physiology of even the tiniest parasitic microorganism. It may well be that other diseases of man can profitably be studied in the light of what we have learned about herpes, even though in those diseases the picture is much more complicated. It may be that some of our violent diseases are merely new forms of old ones that have suddenly been modified, perhaps by mutation. It may also be that these virulent diseases are evolving toward the achievement of a new successful equilibrium with their hosts, and will gradually lose their present virulence. Investigators have not failed to observe that old diseases are disappearing just as new ones are emerging. The theory of the age of disease also offers a clue to the understanding of epidemics. It suggests that they represent sudden, violent disturbances in the equilibrium between a parasitic microorganism and the human host.

Thus the investigation of this harmless, seemingly insignificant virus may well have important results in our defenses against more troublesome diseases. It is clear, for example, that in poliomyelitis, as in herpes, many individuals are infected without experiencing recognizable symptoms. Antibody analyses show that there are 100 hidden cases of polio to every visible one. The science of immunology becomes ever more important as it becomes evident that the individual living in a large community is unable to protect himself against infections from his neighbors, but must rely upon the continuing exploration and research of today's natural historian, whose daily adventures are just as exciting and perhaps more immediately useful than those of his predecessors who sought the tapir, the okapi, or the high-flying condor.

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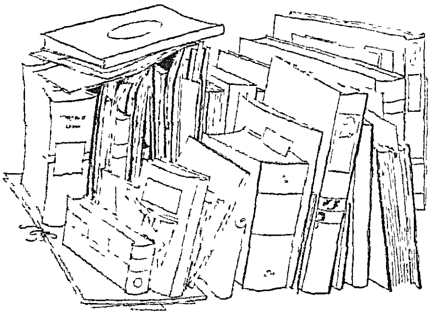


BOOKS

Julian Huxley's summary of the vast debate between the schools of Lysenko and Mendel

by James R. Newman

HEREDITY, EAST AND WEST: MENDEL VERSUS LYSENKO, by Julian Huxley. Henry Schuman ($2.75).

WHAT justification is there for a new book on the Lysenko controversy? Unlike the Abbé Mendel, the Soviet biologist Trofim D. Lysenko has not been a victim of public neglect. At home he has received the highest honors and rewards; abroad, though mostly excoriated, he has been the subject of a torrent of news stories, editorials, articles in popular magazines and technical journals, lectures, political orations and the approving notice of George Bernard Shaw.

Julian Huxley explains in the preface to his book what prompted him to the task. He believes that the controversy over Soviet genetics, for all the words poured out, has not been properly presented. The subject of the debate is highly technical, and its background is a country about which available information is both meager and wonderfully unreliable. In judging the merits of a scientific theory one must apply stricter standards than the easy rules of political debate. Mistrust or hatred of Russia, even when born of disillusionment following a great love, does not fully qualify one to discuss the Lysenko affair; nor is it altogether advantageous to be ignorant of genetics. Even among professional scientists, says Huxley, there has been misapprehension of the nature of the dispute.

Dr. Huxley is uniquely equipped for the job. He is not only a first-rate biologist but a man of broad culture. On his visits to Russia, where he became acquainted with leading Soviet biologists, including Lysenko, he heard their genetic theories expounded at first hand and participated in their discussions, as a former head of UNESCO he had the opportunity to study the international scientific scene and to work for the cause of scientific advancement and freedom. He writes lucidly, with political awareness and disinterestedness. His motives, as his record amply demonstrates, are beyond question.

His book recapitulates the controversy in scrupulous detail; it explains the "role of science and the scientific method in world civilization"; it presents an excellent summary of neo-Mendelian and neo-Darwinian theory. It is a model of intelligent popularization, and a boon to the average reader. Thus Dr. Huxley's essay, though not without obvious defects—it has an air of hurried composition, it is repetitious, sometimes disproportionate in emphasis, and not uniformly persuasive—is an event of unusual social and scientific note in this Soviet-centered debate about opposing theories of heredity.

While the controversy gained worldwide attention in 1948 on the occasion of a special session of the Soviet Academy of Agricultural Sciences, its origins, of course, go back much farther, they may be traced to the writings of the Marxist Fathers and to the circumstances of the Soviet revolution. We may fix attention on the early 1930s, however, as a convenient starting point for the argument among Soviet scientists. At about that time Mendelian genetics fell into marked disfavor in the Soviet Union. Stubborn and outspoken Mendelians began to lose their jobs, "some being banished to Siberia, others sent to labor camps, others just disappearing." Huxley's principal informant on this early history is the Nobel prize-winning geneticist Hermann J. Muller, now at Indiana University, who worked in Moscow from 1933 to 1937. According to Muller, the Soviet geneticist Agol, among others, was "liquidated" in 1936, and S. G Levit, founder of the Medico-Genetical Institute, was forced to make a "confession" of scientific guilt, after which he also vanished. In 1937 an International Congress of Genetics which was to have been held in Moscow was called off by the authorities, when the Congress finally convened in Edinburgh in 1939, all of the 40 Soviet geneticists who had submitted papers were refused exit permits to attend. After the outbreak of war the Soviet attack on "idealist" genetics was intensified, and before 1945 a number of the most distinguished Mendelians had "disappeared from the scene," including Karpechenko, Serebrovsky and the famous Nicolai Vavilov. The latter, as a foreign member of the British Royal Society—a rare honor, for there are only 50—was the subject of repeated official inquiries from the Society to the Soviet Academy. There was never a reply; Muller says Vavilov died miserably in Siberian exile in 1942.

These events were accompanied by the "exaltation" of Lysenko, an obscure Ukrainian experimenter in grain-growing who was gaining fame as the principal advocate of the genetical theories of the late I. V. Michurin, Russian horticulturist and plant breeder (1855-1935). Special conferences were held in Russia in 1936, in 1939 and after the war to publicize the views and accomplishments of Lysenko, to expound the relationship between Marxist ideology and Michurinism, and to "discredit" Mendelism. Lysenko entered political life, was awarded two Stalin prizes and the Order of Lenin, was made a Hero of the Soviet Union and replaced Vavilov in his highest posts.

To the famous 1948 meeting of the Academy of Agricultural Sciences, over which Lysenko presided as president, Huxley devotes many dreary pages. The meeting marked the climax of the Communist assault on Mendelism. Since a printed record of it exists, Huxley's account of the proceedings is tainted by neither hearsay nor fallible recollection. The proceedings are a turgid and idiotic business. The party line in genetics, as there enunciated, runs something like this: Mendelism is "incorrect," "anti-, un-, and pseudo-scientific," "reactionary," "idealist," "inconsistent," "unpatriotic," "bourgeois," "mystic," "metaphysical," "feeble," "scholastic," "alien," and "pernicious." Hereafter the biological sciences as taught and practiced in Russia shall be guided by Michurin's teachings, which are "scientific," "materialist," "progressive," "creative," "effective," "practical," "part of the gold fund of our science," and "correct in ideology." In Soviet scientists' councils "partisans" of "Morgano-Weismannite" genetics are to be replaced by supporters of Michurinite biology; "formal" genetics shall be "rooted out" of Soviet science.

A number of heretics were permitted the opportunity of publicly recanting their errors. A few Mendelians were allowed to defend their views and to come out openly against Lysenko. This was done, Huxley suggests, "to give a semblance of free discussion" and to give the dissenters a rope to hang themselves "They have now all been dismissed or disgraced." Lysenko concluded the Academy meeting with the triumphant announcement that his views had the official approval of the Communist Party, and with the following tribute:

"'Long live the Michurin teaching, which shows how to transform living nature for the benefit of the Soviet people' (applause).

"'Long live the Party of Lenin and

Stalin, which discovered Michurin for the world (applause) and created all the conditions for the progress of advanced materialist biology in our country' (applause . . . all rise . prolonged applause)."

What is "idealist" Mendelism? What are the elements of "Morgano-Weismannite" genetics? What is the nature of the boon conferred on the world by the party of Lenin and Stalin in discovering Michurin? In trying to answer these questions I am forced to make a brief of an expert's brief, which is difficult. I shall quote and paraphrase freely.

Eighty years ago Gregor Mendel discovered "that when different kinds of peas were crossed, certain of their characters retained their distinctiveness in later generations without any trace of dilution or blending, and behaved as if they were transmitted by some kind of

BRANCHED-WHEAT development has been stressed in the U.S.S.R. Some such strains are known in U.S.

definite unit or particle in the reproductive cells—*i.e.*, that the material basis of their heredity was particulate." This conclusion has been confirmed and enormously amplified in the modern science of genetics, which goes under the general name of neo-Mendelism. The existence of the hereditary units postulated by Mendel has been demonstrated, and it is known that these particles, the genes, are arranged in a definite linear order within the cell-organs, the chromosomes. Huxley compares chromosomes to playing cards. There are two full packs in the nucleus of every cell of every higher organism. Before a gamete—a sperm or egg cell—is formed, "a complicated process of pairing and separation takes place so that each gamete has only one pack of chromosomes," containing one chromosome of each kind. Fertilization brings two packs together, one from the egg, one from the sperm.

The Mendelian laws of heredity, as now generally applied in research, are physical and statistical principles which govern the distribution of genes from one generation to the next. The genes, which contain "mainly proteins together with a particular kind of nucleic acid," possess the "essential property of life, in that they are self-copying." Thus there is a continuity of germ plasm, the genes being transmitted from one generation to the next, thereby determining design, rate of growth, function, physique, temperament and so on.

This process extends to yellow-legged chickens, pug dogs, soft-shelled crabs, chestnuts and men. The genes, in sum, constitute the organ, the factory, the architect and the physical basis of heredity. If you have a taste for miracles, the genes imply a miracle of eternal life compared to which the analogous miracles of religion or spiritualism are sticks in the mud.

We come now to a critical point in the argument. "Neo-Mendelism is the science of *variation* as well as of heredity." Variations in organisms of the same species may spring from heredity or from the effects of environment or activity, and the two kinds must be sharply distinguished. Variations of the second kind, such as "darker skin color of white men who have been exposed to plenty of sun," are called modifications. Modifications, the neo-Mendelians assert, are rarely if ever inherited. The only way in which the environment can produce permanent effects is through the evolutionary selection of adaptive traits, with the result, say, in the illustration above, that men who darken more readily in the sun enjoy, with their descendants, an advantage in the struggle for survival in certain climates and societies.

The permanent hereditary variations are due to the occasional random changes in genes known as mutations. "A mutation is a change of measurable extent in the constitution—either a change in qualtity of a single gene, or a change in quantity due to the addition or subtraction of whole genes, sections of chromosomes, whole chromosomes, or whole chromosome-sets." Mutations may come about either spontaneously, or "as the result of some agency such as X-rays, ultraviolet radiation, or certain chemical substances acting on the gene."

Neo-Mendelism and neo-Darwinism together fit into a single system—modern evolutionary biology—in the same way (though with less exactitude) that the facts and principles of modern physics fit into "a single theoretical framework, that of atomic physics." The basis of inheritance is held to be material and almost always particulate, and all characters of adult organisms are ascribed to the interaction of heredity and environment. Evolution results from mutations coupled with selection. In the struggle for existence the possessors of mutant genes will be either at an advantage or disadvantage in their aver-

age ability to survive and reproduce. "Mathematical calculation has demonstrated that quite a small advantage will lead in what is biologically a quite reasonable time to the virtual or total replacement of the old gene by its new mutant representative." In sexual reproduction the "mechanism of heredity . . allows the recombination of characters," *i.e.*, mutant genes may combine with each other or with unmutated genes to produce new combinations of characters This process, more favorable than a single mutation, accounts for many significant and relatively rapid evolutionary changes.

This concept of a world of Mendelian building blocks and processes, with its trends determined by Darwinian selection, has been constructed by scientists working patiently over a period of almost a century. They have used experimental subjects as diverse as chickens, sweet peas, guinea pigs, corn, fruit flies, dogs and tomatoes; instruments ranging from microscopes and spectroscopes to porcelain dishes, pipettes and watering cans, disciplines including mathematics, statistics, physics, biology, chemistry, zoology, psychology, biophysics, biochemistry and even the social sciences. The system is founded on observations and theory, as Huxley says, "inextricably combined." It is subject to modification or even total abandonment as new facts are uncovered and better hypotheses adduced. Among its followers there are sharp differences of opinion and interpretation regarding the meaning of experimental results, and the applications of various principles. It is, however, a coherent whole embodying the best of contemporary scientific method.

Against this system must be measured the theories of Lysenko and Michurin. Their main thesis runs back to the theory of the inheritance of acquired characters, propounded by the French nobleman Jean Lamarck in 1815 He suggested that "detailed adaptive adjustments of the body and its organs to changed environment or way of life are supposed to be able to produce corresponding changes, though of less extent, in the offspring, and to produce them even in the absence of the influences which originally caused the bodily changes in the parent." For illustration, when a land bird took to water, swimming stimulated the growth of a web between its toes, and this webbing was "gradually accumulated by heredity." (To suppose, says Huxley, that a change in the skin of a bird's toes could influence its genes and thus affect its offspring is "like supposing that a telegram sent off from Peking in China will arrive in London already translated into English.")

Michurin and Lysenko have modified classical Lamarckism. They speak first of a "shattering" or "shaking" of heredity by environmental forces. This is supposed to break down the stability normal to the hereditary constitution, thus making it "labile and plastic, or what Lysenko sometimes calls 'unestablished.' " In contrast to neo-Mendelism, which regards the hereditary mechanism (the reproductive organs) as an enclave within the body, only rarely affected by any force or substance acting on the body itself, Michurinism holds, in Lysenko's words, that heredity "is inherent not only in the chromosomes but in every part of the living body You need but change the type of metabolism in a living body to bring about a change in heredity " The mechanics of this change are described by the word "assimilation." Lysenko defines heredity as "the effect of the concentration of the action of external conditions assimilated by the organism in a series of preceding generations."

As examples of Michurinism in practice, Lysenko cites certain experiments. He claims that by a modified method of vernalization—making winter cereals flower earlier by treating the seeds with moisture at a lower temperature—he can turn winter rye, hereditarily, into a permanent spring type. This, he says, shows the effects of changing the enviroment. A second method of "shattering" heredity is "vegetative hybridization"—a special combination of grafting and planting. The third "shattering" method is crossbreeding. Whether or not the term "shattering" has any meaning, crossbreeding is undoubtedly a valid method for producing hereditary changes, and it has proved particularly fruitful, Huxley admits, in the hands of Soviet breeders. Huxley contends, however, that such results can be explained on strict neo-Mendelian lines, "since a hybrid between two strains differing in many genes must inevitably produce a wide range of new gene-combinations, and therefore of characters, in subsequent generations, and the best of these can then be isolated and purified by selection."

Huxley disputes Michurinism in almost every particular. He charges, in the first place, that the Michurinites' whole attitude is unscientific "they do not normally employ scientific controls, statistical tests, or the usual scientific precautions, such as concern for purity of material", their publications of methods and data are frequently so inadequate as to prevent verification, they "repeatedly make incorrect statements of fact" as to the work of others. Secondly, while vernalization itself is an established fact, "the hereditary conversion of winter into spring cereals through a few years' partial vernalization, as claimed by Lysenko, is *not* an established fact." Lysenko's experiments have not been confirmed; his results are "almost certainly" no proof of Lamarckian inheritance; he neglects the effects of selection, which here and elsewhere simulate Lamarckism. Huxley similarly criticizes the results claimed for "vegetative hybridization," emphasizing Lysenko's use of impure strains.

None of the numerous claims made by classical Lamarckism, says Huxley, has ever stood the test of criticism and repetition. Strong evidence against it has been marshaled in the famous mathematical researches of the British geneticist Ronald A. Fisher. Though Lysenko's Michurinism modifies Lamarckism by postulating that its effects can take place only after the "shattering" or "shaking" of heredity, this has not been proved either, nor can the postulate be "easily reconciled with various facts that are established." Huxley concedes that many observed phenomena are not inconsistent with Michurinism, but he argues that they can all be explained as well or better by neo-Mendelism and neo-Darwinism. On the other hand, Mendelian genetics is able to explain a host of other phenomena that do not fit into the Michurinite system. This is, of course, the crucial test of the validity of a scientific system—its inclusiveness, economy and ability to account for divergent phenomena.

Huxley also censures Lysenko's repudiation of the methods of mathematical probability and statistics He says that Lysenko appears to understand little of mathematics, and in any case seems to be unwilling to accord a place to chance and indeterminacy in his scientific system, nothing short of certitude will do. Observing that attacks on the mathematical theory of probability have come from other quarters in the U.S.S.R., Huxley takes this as evidence that probability theory is incompatible with Marxism, or at least with Marxist ideology as now interpreted. However this may be, we do have Lysenko's own arguments that the "so-called laws [of neo-Mendelism] . . are based entirely on chance", that "with such a science it is impossible to plan to work toward a definite goal", that physics and chemistry have become "exact sciences" only as they rid themselves of "fortuities", and, finally, that "Mendelism-Morganism" must be banished from "our science," because "we must firmly remember that science is the enemy of chance "

Some of Huxley's criticisms must, of course, be left to the judgment of other experts; some are easily accessible to the general reader's understanding. The descriptions of Lysenko's personal attributes, to which Huxley devotes considerable attention ("a peasant," "practical," "a zealous Communist," "not a charlatan," "sincere," "fanatical," "a medieval mind using what is almost a medieval technique"), serve to explain the vehemence of Lysenko's opinions and the ideological bias underlying his side of the controversy. Lysenko is an easy target for ridicule, and the book contains many choice samples of his astounding opinions.

Yet Huxley weakens his case by omis-

sions and overstatements. The nature-nurture controversy, decades old, continues to bubble even in the Mendelian pot. Many aspects of modern genetics and neo-Darwinism are not only enormously complex but admit of wholly contradictory inferences. Even in physics, a science much more exact than genetics, our period is witness to remarkable antitheses of fundamental theory. The fashionable current view that physical laws are only statistical averages is rejected by no less an authority than Albert Einstein, who holds to deterministic theory and refuses to believe that the behavior of matter is a "fundamental game of dice" [his words in a letter to Max Born]. Huxley does not adequately acknowledge the differences among classical geneticists. In the role of advocate he seems unwilling to admit that his own cause is afflicted by internal divisions. Scientists in general, geneticists not excepted, have the usual social, political and economic preferences. Huxley knows of course that the outlook of an investigator, honest and independent though he may be, affects his scientific interpretations and conclusions. This book makes clear the relation between social and political dogmas and Lysenko-Michurinism; it neglects to make the same searching inquiry regarding neo-Mendelism and neo-Darwinism. This is not to imply that Western scientists are dishonest, or to suggest that orthodox genetics is not, by scientific as well as pragmatic standards, vastly superior to Michurinism. It would have been better, however, to draw the Western portrait with its warts. Huxley's case would still have been overwhelming.

The last phase of Huxley's analysis attempts to answer the question. Why has Michurinism found favor in the Soviet Union? The reasons are not altogether obvious and it is necessary to be reminded of the broad setting.

The subordination of many forms of intellectual activity to Marxist philosophy, and the imposition of state controls to enforce conformity, are by now a familiar aspect of Soviet life. This has taken place, in varying degrees, in history, music, philosophy, law and science. Thus far, however, the other sciences have not been caught up in the ideological mill as directly as biology; there is no "party line" for chemistry, geology, mathematics and so on, except, as we have noted, in probability theory and statistics.

The "socialization" of biological science has proceeded along lines of "appeal to immediate utility . . . to national patriotism and class sentiment, so that science is regarded primarily as an instrument of the class struggle and its national extensions." In accordance with the principles of dialectical materialism, Soviet intellectuals have found it necessary to justify a philosophical doctrine or scientific theory as materialist, and in turn to reject any doctrine or theory "to which there attaches a suspicion of idealism." The term "materialism" is thus used not only with its usual classical philosophical connotation, but as a "certificate of value," a "label . . . of praise and commendation, to denote conformity with official dogma."

Neo-Mendelism also rests on a belief in the material basis of inheritance One is puzzled, therefore, as to why this system is denounced as "idealist" and "anti-materialist." Huxley suggests an explanation. Lysenko and his followers use these terms, without much regard to meaning, simply because they are the accepted style of denunciation, and because "it pays to do so in order to emerge victorious in the dispute."

It is less easy for a scientist to understand why the scientists of the Academy as a whole back Michurinism, "whose facts are notoriously and obviously dubious and whose crude interpretive principles bear no resemblance to a scientific theory in the accepted sense." This endorsement is the more perplexing in view of the fact that, as Huxley points out, "Russian science in general stands at a high level." Moreover, it strains at plausibility to make out the Russians, as American official and newspaper opinion has attempted to do, as diabolically ingenious and quarter-witted at the same time. To be sure, the totalitarianism of the U.S.S R. would account for the Academy's blessing once the political authorities had laid down the rule. But why were the politicians won over? Huxley offers two reasons.

The practical reason is that the U.S.S.R. is "economically and technologically a backward country." Russia is desperately dependent upon an increase in agricultural yield, and Lysenko's theories hold out the promise of a more rapid increase than does Mendelism. His results since 1935 have "seemed evidence of successful achievement." In the long run, Huxley comments, Mendelian methods of breeding would have paid off more richly, but Lysenko, capitalizing on his country's agricultural backwardness, including its unimproved and genetically impure strains of crop plants and livestock, has "energetically" introduced superior agronomical methods and produced some quick results. His methods have had "a salutary effect."

The second reason for Lysenko's political backing is ideological. Mendelian heredity is disliked in the Soviet Union because it locks man into a groove of predestination and implies both "human inequality" and "human helplessness." Such, at least, is the popular misapprehension, though responsible Mendelians would regard these pat notions as absurd. Marxist politicians might be expected to swallow such ideas, to embrace Lamarckism with its "promise of speedy

control," Lysenko-Michurinism with its simple, easily comprehensible methods. No choice could be more compatible with Marxian ideology, nor, indeed, with the aspirations of a society professing egalitarianism, struggling to overtake the Western world and to overcome the handicap of centuries of enslavement in poverty and ignorance. Soviet political opinion was the more readily impelled to accept Michurinism because Mendelism, or the idea of genetic inequality, had been used by the Nazis, and continues in use by bigots, fools, and reactionaries elsewhere, to justify social practices based on racism. The truth is, of course, that Mendelism no more requires the acceptance of racism than "acceptance of the biological struggle for existence as a fact means that war is a good thing in human affairs."

"Actually," writes Huxley, "the effect of environment and social conditions is often so large as quite to mask the underlying genetic inequality; and the genetic variability of the human species is so well distributed that the average genetic difference between different classes or social groups and different nations or ethnic groups is negligible or small in its effects, compared with the improvements which can be effected through better living conditions and better education Similarly, genetic predetermination is not absolute, environment is needed for the unfolding of man's potentialities."

I recommend Dr Huxley's book, especially to those who hold to the old-fashioned beliefs that truth is the means to freedom, and understanding the means to peace

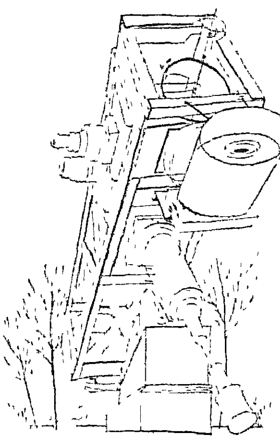
SOCIAL-CLASS INFLUENCES UPON LEARNING· THE INGLIS LECTURE, 1948, by Allison Davis. Harvard University Press ($1.50). ELMTOWN'S YOUTH. THE IMPACT OF SOCIAL CLASSES ON ADOLESCENTS, by August B. Hollingshead. John Wiley & Sons, Inc. ($5 00). ADOLESCENT CHARACTER AND PERSONALITY, by Robert J. Havighurst and Hilda Taba. John Wiley & Sons, Inc. ($4 00). THE PSYCHOLOGY OF SOCIAL CLASSES: A STUDY OF CLASS CONSCIOUSNESS, by Richard Centers. Princeton University Press ($3 50) When citizens of the United States are asked whether they belong to the upper, middle or lower class, the great majority choose the middle class This result, consistent with the notion of America as the land of equal opportunity, has led some people to conclude that consciousness of class is not a factor in the life of the United States. Traditionally, in America, anyone is equal to anyone else, and wealth, education, family—in a word, class—are not important. The testimony of these four books contradicts all of this. In sober language the authors describe the classes into which American society is organized, and they go beyond this description. For one's experiences in childhood and adolescence, when attitudes are being formed and when the mind itself is being trained, are strongly conditioned by his class membership. In adult life, too, class may determine one's voting behavior, and political and social attitudes and beliefs. Dr Davis summarizes studies which show that intellectual functioning differs among the social classes. The pattern of intelligence, as measured by tests, varies with class, and it is clear that the school, which stresses middle-class beliefs and values, is unable efficiently to teach or even to communicate with those of its students whose parents are laborers, factory hands, clerks and the like. Dr. Hollingshead, in *Elmtown's Youth,* describes the class structure in a typical midwestern town and shows in detail how class membership affects the lives of over 700 adolescents of high-school age. The high school is dominated by the higher classes (classes I and II). High-school parties, plays, clubs, awards and scholarships are largely theirs. Religious clubs and adolescent cliques seldom include members from more than two classes, and social intercourse between class Vs (the lowest group) and class Is and IIs is rare indeed. Many adolescents of high-school age, mostly from classes IV and V, had withdrawn from school, their jobs, recreational pursuits and marriages are markedly affected by class lines. There is little opportunity for them to rise above the kind of lives led by their class IV and class V parents. Similar findings are reported in *Adolescent Character and Personality* A group of specialists studied 16-year-old adolescents in "Prairie City," some of whom had been studied by Dr. Hollingshead in "Elmtown." Character (reputation) is highly related to school achievement, which depends in good part upon conformity to the school's middle-class values and expectations. "Good Character" then will be fostered in families whose values are the school's values, and this is a class matter. Dr. Centers, through Princeton's Office of Public Opinion Research, found that the majority of a sample of white, male adults was divided into two classes, the middle class and the working class In a large number of areas—representative ones are political behavior, attitudes toward jobs, religion, and chances for advancement—the two classes differed greatly in their expressed viewpoints. At least this conclusion can be reached from these four books· By his class, ye shall know him.

JAMES MCKEEN CATTELL: MAN OF SCIENCE. Volume I, Psychological Research, Volume II, Addresses and Formal Papers. Edited by A. T. Poffenberger. The Science Press ($10.00). Cattell would not write an autobiography, giving as an excuse his unwilling-

ness to appear as a defendant in numerous libel suits. It would have been fascinating, for he was not only the first American professor of psychology and one of psychology's foremost early leaders but he was also active in scientific organizations, a publisher of scientific journals, and vocal in the fight for academic democracy and freedom. Above all, he believed in science. "It may be urged reasonably that science is the true cause of democracy . . .," he wrote in 1912. Science, education and democracy were the major concerns of his active, productive and influential life. Some of his writings are brought together in these two volumes. Volume I includes many of his psychological research papers. His psychology was objective, quantitative, practical and rigorous in method. Volume II contains some of his work as a statesman of science.

THE PROBLEM FAMILY, by A. S. Neill. Hermitage Press, Inc. ($2.75). In the foreword to this outspoken and readable book Goodwin Watson of the Columbia University Teachers College describes the reactions of a group of American educators who visited Summerhill, a British progressive school run by Mr. Neill. "Some of us," writes Watson, "were delighted and others were shocked. No one was indifferent." Readers of *The Problem Family* will probably react similarly to Neill's opinions. He lashes out against cruel, hypocritical and fear-instilling educational methods, Buchmanism and many aspects of organized religion, and every conventional parental device for compelling conformity and obedience. An uncompromising foe of humbug, but himself an advocate of some views that would be regarded as humbug by enlightened, if less unorthodox, educators, Neill merits a hearing for his fresh, honest approach and because he is so obviously a man who understands and loves children —sick, complicated and difficult children even more than normal ones.

SCIENCE SURVEY, edited by Ian Cox. Samson Low, Marston & Co. Ltd., London (21 shillings). If you have listened to what the average radio station passes off as a science program, the British Broadcasting Corporation programs gathered in this book will provoke odious comparisons. Most of the talks are by leading British scientists (Sir Henry Dale, Sir Charles Darwin, E. N. da C. Andrade, J. B. S. Haldane, Sir Robert Robinson, Sir Lawrence Bragg, Sir Harold Spencer Jones, Sir Edward Appleton and many others), the subjects have been carefully selected and range over the widest possible field, the presentation is lucid and entertaining, the audience is assumed to consist of intelligent adults. A model collection which, one wishes, would inspire domestic impresarios to go and do likewise.



THE AMATEUR ASTRONOMER

Conducted by Albert G. Ingalls

THE Palomar Mountain Observatory possesses the largest existing examples of two opposite types of star cameras: the 200-inch—still called a telescope though it is used only photographically—which takes pictures of very narrow areas but penetrates space to a distance of a billion light-years, and the 48-inch Schmidt, which reaches only one third as far as the 200-inch but photographs areas many times wider.

The 48-inch Schmidt is now beginning its first work as a systematic scout for the 200-inch. During the next four years it will photograph, area by adjacent area, in both red light and blue, the whole of the sky that is visible from its latitude—three fourths of the entire area of the heavens. The result will be an album of a thousand pairs of photographic prints, costing $2,000 a copy, which will be used by other observatories

As this program swings along, at the rate of one exposure an hour when the skies are clear, new discoveries almost surely will be made as by-products: data on variable stars, on novae, on clusters, and unexpected finds. a new asteroid has been found already. What, then, is the principle of the Schmidt, and where did it get its name?

Bernhard Schmidt, the son of Swedish and German parents, was born in 1879 on Nargen, an Estonian island between Estonia and Finland. After studying optics in Sweden he moved to the vicinity of Jena in Germany, where he lived a carefree life for 25 years, occasionally making telescope mirrors to sell to amateur and professional astronomers. He ground them not only by hand but with only one hand, he had lost his right hand when he was a boy. He never married. Dr. Paul C. Hodges, who has investigated his life, says that Schmidt's wants were confined to simple lodgings, food, cigars, cognac and freedom from regimentation. He would undertake no more mirror making than would barely satisfy these few needs, and refused positions with the large optical manufacturers.

In 1926, however, he was induced by astronomers of the Hamburg Observatory in Bergedorf to join the staff as a "voluntary colleague," an arrangement that gave him freedom to roam the woods and talk to himself. In regimented Germany this loose kind of arrangement might have cost the director of the Observatory his job but, as Dr Hodges states, "instead it gave the world the Schmidt camera" Schmidt announced its discovery in 1932. He died in 1935, but not before the significance of the basic principle he originated had been recognized by science. Even greater realization of its importance has come since his death.

This is the problem that Schmidt solved: If only a spherical mirror could be used in a reflecting telescope, the telescope would be free from the blurring aberration called coma Unfortunately a spherical mirror suffers from another cause of blurring called spherical aberration To remove this spherical aberration the sphere is "corrected," that is, slightly deepened toward the center to make it a paraboloid. This correction in turn introduces coma, which, for critical uses such as star photography, blurs all images not in the center of the field. Thus in picking up one bundle the second bundle is dropped.

Bernhard Schmidt discovered a way to carry both bundles. He analyzed the problem thus. A correction equivalent to a paraboloid could be made on a separate plate of glass in contact with the original spherical mirror. From this, however, there would be no gain, as many others had realized after having the same analytical thought. Schmidt's stroke of genius was to think one more thought—and, of course, the right one. He removed the plate from contact with the spherical mirror and shifted it several feet to the center of curvature of the sphere Here both kinds of aberration were eliminated at once, making possible a sharp focus over a broad area on the photographic plate. By easy hindsight, most optical workers have noted how simple the Schmidt principle is, and have kicked themselves for not discovering it first.

Cameras like the 200-inch that have paraboloidal mirrors can photograph, blur-free, areas of the sky only about one sixth of a degree in angular diameter, represented approximately by holding a pin at arm's length with its head facing the eye. The 48-inch Schmidt at Palomar can photograph areas six degrees in angular diameter, represented by holding three fingers at arm's length against the sky. The ratio between the two areas is about one to 900. This gain was Schmidt's great gift to astronomy.

The six-degree angular diameter of the area photographed by the 48-inch Schmidt is almost the same as that achieved by a Schmidt camera built by the amateur astronomer John F Gregory of 3825 Bainbridge Road, Cleveland Heights 18, Ohio. This does not mean that Gregory's 5-inch Schmidt, shown on page 63, equals the great Palomar Schmidt in all respects It has very much less power to penetrate distant space.

On the opposite page is a photograph of the Double Cluster in Perseus and surrounding stars made by Gregory's Schmidt. The original of this photograph, a little round film only 1⅜ inches in diameter, was shown, together with photographs of the Gregory instrument, to Dr Henry Paul of Norwich, N. Y., an advanced amateur authority on the Schmidt. The Perseus Cluster photograph evoked praises not often given to or justified by similar attempts. "Very good in many, many respects." The images of individual stars are small and round, showing no aberrations, clear out to the edges of the film

GREGORY is a senior student in mechanical engineering at the Case Institute of Technology in Cleveland. Ten years ago, at the age of 12, he attended a lecture by J. J. Nassau, head of the department of astronomy at Case. A year later, with the help of the book *Amateur Telescope Making*, he had completed a beginner's reflecting telescope. Wisely, he waited to acquire more years and experience before tackling a Schmidt.

The lightweight tripod shown in the illustration is temporary, being found too shaky on breezy nights. Bolted to the top of the tripod is a block of oak. To this the electric driving motor and the driving-speed reduction gearbox are bolted below, the mounting and tube are bolted above. The main casting of the mounting, as well as the fork and the gearbox, are of aluminum. Gregory "patterned," cast and machined them as a special project while taking required courses in these subjects at Case. The sloping polar axis is mounted in a ⅝-inch radial ball bearing at its lower (south) end. Another bearing of 1¼-inch diameter at the upper end of this axis absorbs the end thrust due to the camera's weight.

The drive that keeps the camera in motion to compensate for the earth's rotation consists of a Warren C5M synchronous motor rated at 12 watts and costing $13. It is attached to the lower end of the gearbox and rotates at four revolutions per minute The drive passes through a differential like the one shown on page 323 of *Amateur Telescope Making—Advanced* (to permit the use of a flexible cable for hand guiding during

photographic exposures), then to 18- and 15-tooth meshing spur gears, next to 61- and 75-tooth gears. All are Boston Gear Works stock gears. All the shafts are mounted on ball bearings. Where it emerges from the gearbox the drive is connected with the camera by a vertical shaft with jaw coupling which permits disconnection of the gearbox from the unit. The next gear, above the oak board, is a worm and 60-tooth worm gear pressed directly on the main worm shaft of the polar axis. The worm wheel has 96 teeth.

The tube of the telescope was made by a local sheet-metal worker who rolled up and butt-welded a sheet of .050-inch-thick 3S½H aluminum that cost $1.70 at a local warehouse of the Aluminum Company of America (general office: Pittsburgh, Pa.).

"The primary mirror was made from a 6-inch plate glass blank, ground and figured to a sphere of 14-inch focal length," Gregory says. "Thus if the 5-inch stop in the focal plane were removed the focal ratio would be 2⅓, but with it the working focal ratio is *f*/3. The 5-inch stop provides for equal illumination over an area as large as a 4-inch stop would provide if placed at the mirror's center of curvature. Because the curve is so deep, the figure tended to remain spherical during polishing and little trouble was experienced in figuring.

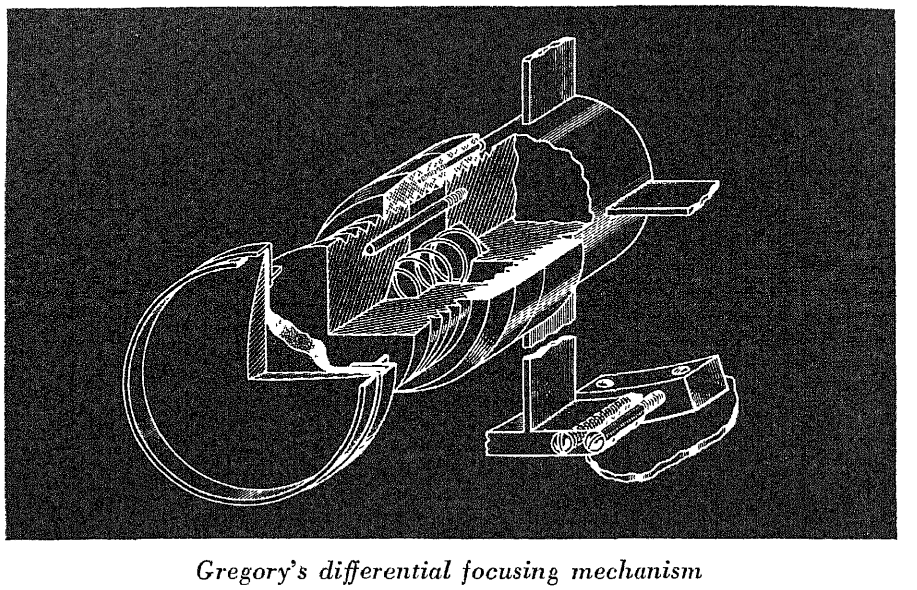
"The glass for the correcting plate was from an Air Corps filter I thought this glass would be flat enough, but I had to grind it flat with No. 600 Carborundum."

For the correcting plate Gregory chose the type of curve based on $k=1$. This gives a curve that is worked from a plane surface with a neutral or deepest zone .707 of the distance from the center of the plate to the edge. "Having drawn the curve," he states, "I cemented half-inch-square glasses, cut from a two-inch-square slide cover glass, to a sponge-rubber kneeling pad, with most of the squares at the radius of the thinnest zone, tapering off gradually toward the center and very rapidly toward the edge. After 15 minutes' grinding with finishing emery, and an hour's polishing with cerium oxide on HCF backed with sponge rubber, the lens was ready to test.

"The test described by Lower in *Amateur Telescope Making—Advanced*, page 412, was found to be satisfactory, but I used a Ronchi grating instead of a slit, making it by photographing a coarse grating on film to give about 80 lines per inch. Placing this film at the focus (within half an inch) and viewing the mirror through the lens from a distance of 10 feet or so, I discovered that all except the outer inch was satisfactory. Regrinding, polishing and testing from 30 feet finally gave a much-longed-for appearance of parallel lines.

"The longitudinal focusing mechanism I evolved is shown in the drawing. It is the easiest arrangement I know of

John Gregory's Schmidt photograph of the Double Cluster in Perseus



Gregory's differential focusing mechanism

for 'squaring-on' the spider and finding the focus precisely, micrometrically, yet quickly. I threaded a short stud one inch in diameter with 24 threads per inch and press-fitted it to the spider. A second stud, movable, was threaded with 20 threads per inch. A rotating brass collar was made in two pieces, one half threaded with 24 threads per inch and the other with 20 threads per inch, and the two halves joined with screws. This collar moves the movable stud longitudinally at a very gradual, controllable rate. As the collar is turned one revolution it moves *on* the fixed stud 1/24 inch, but at the same time *off* the movable stud 1/20 inch. Since the movable stud is constrained against rotation by a concealed pin shown in the drawing, it moves only 1/20 inch—1/24 inch, or a delicate 1/120 inch, with respect to the stationary stud.

"In adjusting the focus, which is delicate on a Schmidt, where everything is critically sensitive, a series of exposures are taken without moving the plateholder on the stud. After each exposure the collar is rotated, the camera also being moved in declination so that the next exposure will not fall on the first. In this manner one can focus and square-on after about three test plates.

"The plateholder fits over and remains on the movable stud by friction, and consists of a camera filter adapter, a flat metal back-plate, a black paper disk, the film held flat, and a crown glass plano-convex field flattener lens (radius of convex curve 5 inches), all in the stated sequence and all pressed into mutual contact by the retaining ring. The field flattener for the convex field characteristic of the Schmidt camera was resorted to after unsuccessful attempts to keep the film from humping out of contact with the conventional convex base. Except for flare due to reflection around bright stars, it has worked very well, especially since it was coated.

"On nights with no haze or smoke I can expose for an hour before sky illumination fogs the film.

"The guide telescope is a 2-inch refractor and is too small: it is unfortunately very hard to guide on faint stars with it.

"For visual observation I have a diagonal and a 16-mm orthoscopic ocular, held on a metal plate that fits over the side of the tube. Because of the steep cone of light, images are good over no more than a three-degree diameter field, but most Schmidts are not used visually at all."

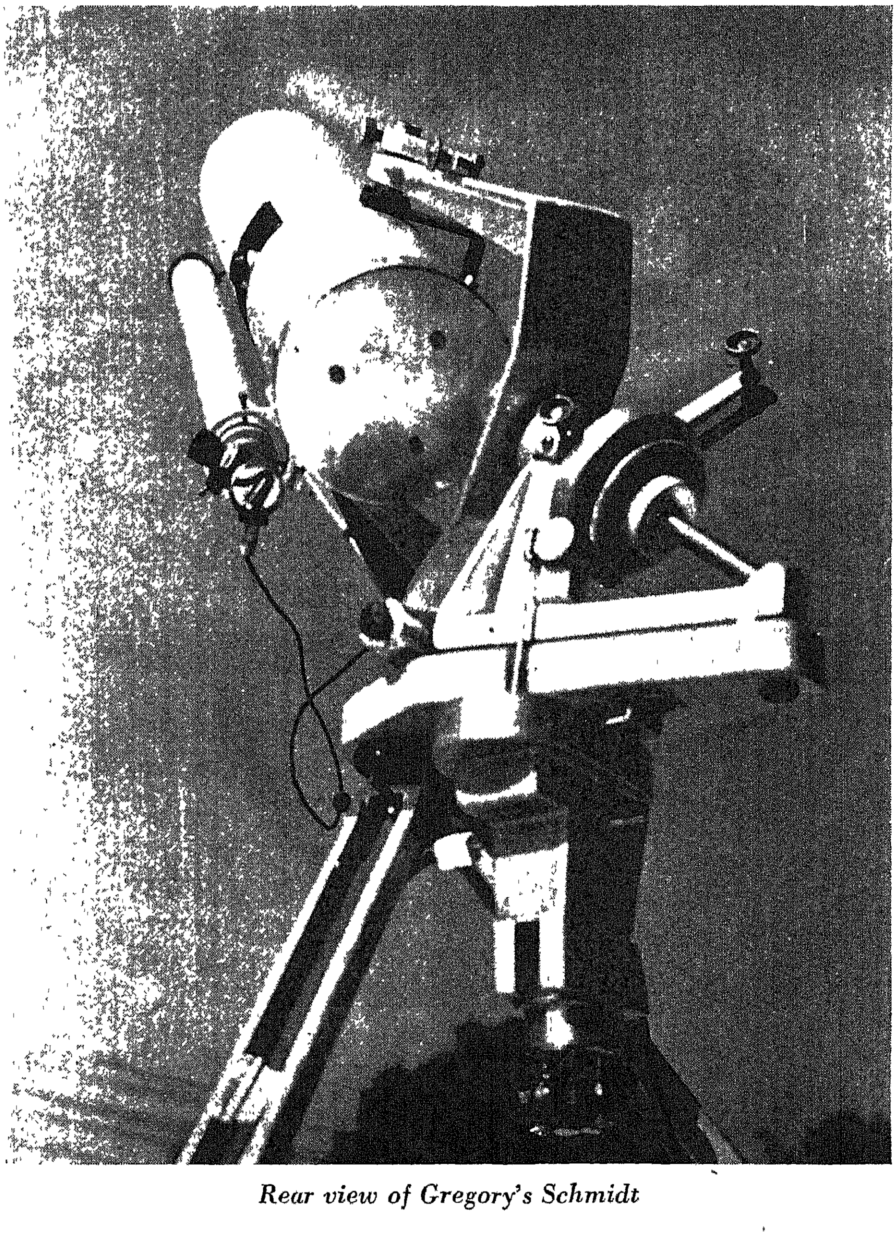
ONE more source of puzzling scratches on optical surfaces has been tracked down. Carl E. Wells of Roseville, Calif., reports that D. A. McLaren of Hunter's Point, Calif., was long baffled by unaccountable scratches, as are many other workers. His inspiration was to examine the chamfer at the edge with a microscope. He was astonished to note the manner in which this part was fractured. Acting on the hypothesis that these tiny fractures break off during polishing and scratch the glass, he threw away the Carborundum stone used to make the chamfer and substituted a piece of glass and loose Carborundum grains No 600. This stratagem finally put an end to his scratches

Ironically the use of a Carborundum stone for chamfering is recommended in *Amateur Telescope Making* (pages 286 and 296) for the prevention of scratches! It prevents some scratches in a manner that apparently causes others. The history of the telescope making art from its beginning has been one of additional learning.

OUR SUN, by Donald H. Menzel, assistant director of the Harvard College Observatory, covers the current status of solar research from all its major angles: an easy approach, the basis of astrophysics, solar chemistry, the problems of sunspots, or solar cyclones; fine

details of the solar surface, solar prominences as phenomena of explosiveness; the corona mystery; atomic energy and the sun's interior, solar eclipses, and the sun as a source of energy for man's use This coverage is as broad and as deep as that of a textbook with the happy difference that, not being dragged down by the consciousness that he is writing a textbook for use in the discipline and to be criticized as such by others, an author can write more readably and the publisher can print more attractively. The result, in the present instance, combines the values of both qualities. Dr. Menzel has done much writing for lay readers and his style is as straightforward and unstilted as that of a lecturer before an intimate audience. The subjects dealt with are technical, the book is by no means light. It deals with solid subjects at the upper middle level of understanding.

Another new book is *Skyshooting*, by R. Newton Mayall and Margaret L. Mayall. It calls to the attention of owners of ordinary cameras a wide variety of easily available photographic activities that many of them have missed, probably because precise instructions have not been available. The activities systematically and practically, not loosely, dealt with are· photographing star trails, a first approach; photographing the aurora preferably with Leicas and with fast or color plates, a next step in the order of difficulty, meteor photography, which will call for patience and tenacity, photography of selected star fields, using ordinary cameras or homemade box cameras (a simple design is described) together with guiding aids on simple equatorial mountings, photography of variable stars at intervals that reveal their changes, photography of new stars, comets, clusters and nebulae, and of sun, moon and the planets. Data on exposure time and development are included in this practical and self-contained working book Beginners in astronomy will find more new data in this book than advanced amateurs. The junior author is a member of the staff of the Harvard College Observatory.



Rear view of Gregory's Schmidt

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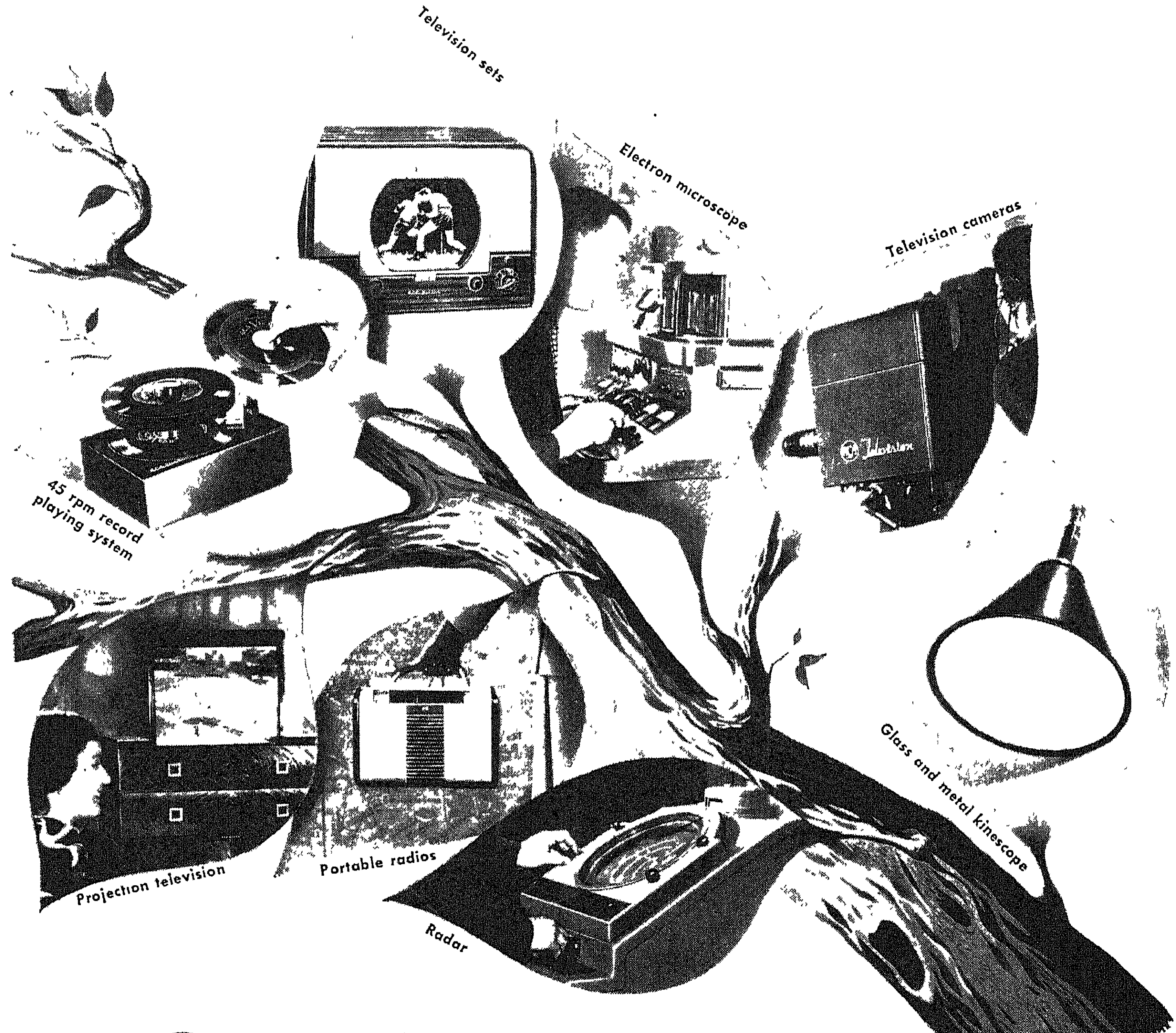

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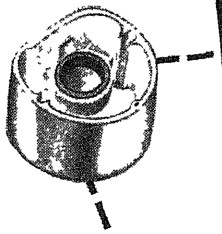

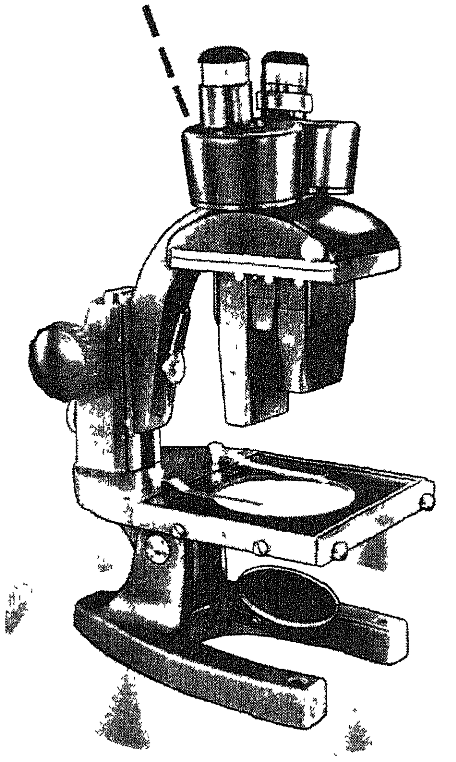

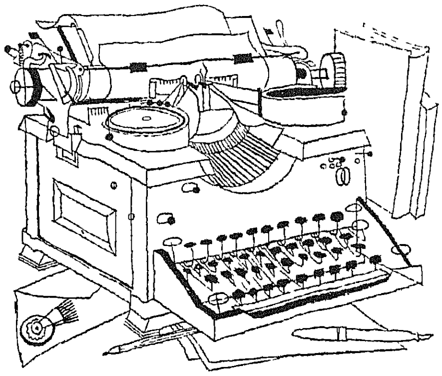

Sirs:

This letter will not discuss material that has appeared in *Scientific American*, but will report an event that should be of interest to your readers.

The ever-increasing specialization in all fields of human endeavor has had at least one very unexpected result: the decay of our civilization, which can in part be traced to the disregard of moral and ethical values.

In former times scientists were inevitably also concerned with the philosophical quest for the meaning of the universe and man's place in it. This quest led automatically to an establishment of moral values.

Specialization has resulted in a complete separation of professional problems from ethical ones. Scientists—like other people—sell their skill, as it were, in the market place. This does not mean, however, that scientists have no ethical or moral values It does mean that in general they do not attempt to apply these values to the selection of the problems they work on.

Recently a society—the Society for Social Responsibility in Science—has been formed which links men and women who do not agree with this compartmentalization and who, being aware of the social responsibilities of their work, are determined to apply viewpoints of ethical and moral values to the selection of it. In our present-day society this is not easy because from a moral and ethical viewpoint mass killing is not admissible, and yet the greatest part of the scientific endeavor at present is controlled by and devoted to military aims, which implies mass killing.

The constitution of the above-mentioned society states its aims to be as follows: "to foster throughout the world a . . . tradition of personal moral responsibility for the consequences for humanity of professional activity, with emphasis on constructive alternatives to militarism, to embody in this tradition the principle that the individual must abstain from destructive work and devote himself to constructive work, according to his own moral judgment; to ascertain . . . the boundary between constructive and destructive work, to serve as a guide for individual and group decisions

LETTERS

and action; to establish and operate an employment service . . . for those individuals whose convictions necessitate leaving or refusing destructive work, to assist those individuals who suffer economic or legal difficulties because of . . . abstaining from . . . destructive activity."

VICTOR PASCHKIS

President, Society for Social
Responsibility in Science
Neshanic Station, N. J.

Sirs.

Your article entitled "Enzymes in Teams" by David E. Green is very interesting and well done. However, I would like to point out that the author evidently is not acquainted with an important piece of work done in this field. He states, ". . . in the animal body the conversion of glycogen to glucose or of glucose to glycogen is profoundly affected by hormones such as adrenalin or insulin. But no one has succeeded in showing that the reconstructed process in the test tube is sensitive to the action of these hormones, in other words, it has yet to be demonstrated that insulin or adrenalin act on isolated enzymes."

Colowick, Cori and Slein state in the *Journal of Biological Chemistry*, Vol. 160, p. 633, 1945, and Vol. 168, p 583, 1947, that hexokinase, which catalyzes the reaction: glucose + adenosine triphosphate $\longrightarrow$ glucose-6-phosphate + adenosine diphosphate is inhibited both *in vivo* and *in vitro* by adrenal cortical hormone and anterior pituitary hormone working in cooperation, and that this inhibition is antagonized by insulin. The above reaction is a step in the conversion of glycogen to glucose and *vice versa*

CLARENCE M. COBB, JR.

Blue Island, Ill.

Sirs.

Careful reading of the papers from the Cori laboratory will disclose that the inhibitory effects on hexokinase which were reversed by insulin were brought about by *extracts* of anterior pituitary and adrenal cortex. There is no published evidence that the effects of these extracts can be referred to any of the known hormones. Various investigators have extended these original observations of the Cori group and there is now more information about the specificity of the effects brought about by the glandular extracts. Mirsky and Broh-Kahn have reported that extracts of spleen like the glandular extracts can produce inhibitions of hexokinase which in some cases are reversed by insulin. Stadie and Zapp have also published an extensive study which does not support the view that the physiological role of insulin is that of relieving the inhibition of hexokinase induced by diabetogenic hormones. Thus there is in my opinion no conclusive published evidence that hormones can act on highly purified enzymes in the same way as they are known to influence these same enzymes in the intact cell or tissue.

DAVID E. GREEN

Institute for Enzyme Research
The University of Wisconsin
Madison, Wis.

ERRATA

The chart of the International Phonetic Alphabet that appeared on page 23 of the September issue of this magazine was not properly credited. It is adapted from *The American College Dictionary* with the kind permission of the copyright owner, Random House, Inc.

The caption on pages 38 and 39 of the November issue, pertaining to the penetration of space achieved by the 200-inch telescope, contained the figure "thousand billion light-years." This should have been "thousand million light-years."

Scientific American, December, 1949, Vol 181, No 6 *Published monthly by* Scientific American, Inc., Scientific American Building, 21 West 40th Street, New York 18, N Y , Gerard Piel, president, Dennis Flanagan, vice president, Donald H Miller, Jr., vice president and treasurer Entered at the New York, N Y Post Office as second-class matter June 28, 1879 under act of March 3, 1879 Additional entry at Greenwich, Conn

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50 AND 100 YEARS AGO

DECEMBER 1899. "Mars may almost be said to have lost his popularity of late. During the last opposition comparatively little was seen of the puzzling system of streaks called canals, which have given birth to so many fancies concerning Mars, and almost nothing new seems to have been learned. It is true that the planet was not well situated for observations, but at the same time disappointment has been felt over the meager results obtained."

"How have our views as to matter changed and how are they constantly changing! We cover the atom with patches of electricity here and there and make of it a system compared with which the planetary system is simplicity. Nay more: some of us even claim the power, which Newton attributed to God alone, of breaking the atom into smaller pieces whose size is left to the imagination."

"The stupendous Zeppelin airship is now nearing completion on its floating dock in Lake Constance. Its proposed speed is 22 miles an hour, and hence it will be helpless against a wind of that velocity. It is in providing a motor sufficiently powerful to propel the huge structure against a strong opposing wind that the difficulty lies This has never been accomplished as yet, and there is no expectation that even the mammoth Zeppelin airship will be able to make headway against anything stronger than a moderate breeze. Nevertheless, if this distinguished German succeeds in achieving this speed with an airship capable of carrying a crew of several men, he will have placed the problem of aerial navigation on a practical basis which it has never hitherto reached."

"The present indications are that as long as balancing is dependent upon the sensations and voluntary control of the operator, aeroplane navigation will remain a very hazardous and fatal form of recreation. It is evident that some method of automatic mechanical control is necessary, and the results achieved by Professor Langley on the Potomac River indicate that such control is within the possibilities of the future. In perfectly still air the Langley steam-driven aerodrome achieved a steady flight of three-quarters of a mile at a speed of thirty miles an hour. But although this was a truly wonderful result and speaks eloquently for the skill and unconquerable perseverance of the inventor, it is a far step from that to a machine of commercial or military utility, capable of carrying its freight in any direction in all possible conditions of wind and weather."

"In recent years bacteriological science has proved beyond the possibility of cavil that in the great cycle of change, from the organic matter in the soil to the elaborate products which are absorbed by the roots of the plant, the bacteria of the soil are the great, and indeed the only agents employed. It is also a proved fact that the wart-like excrescences on the roots of leguminous plants are the camping grounds of myriads of bacteria which possess the property of being able to absorb the free nitrogen of the atmosphere and render it favorable for the use of plants."

"President McKinley has at last ridden in an automobile actuated by steam."

"The success of the Holland submarine torpedo boat, recently made at Peconic Bay, on the north coast of Long Island, assuredly marks the advent of a new era in the development of submarine craft designed for offensive operations in war. The vessel was on several occasions under water for intervals of more than twenty minutes, and demonstrated her ability to respond to a summons to sink beneath the surface, approach a ship, discharge a torpedo, wheel about in her course and return to a place of safety, all within a space of considerably less than half an hour."

DECEMBER 1849. "Some of our railroads, we hear, are experimenting with soft coal. It is time that wood was dispensed with by our railroads. Our forests, vast though they be, deserve a better fate than to be eaten up by the iron horse, when fuel from beneath the surface of the earth will do just as well."

"Two gentlemen a short time since, ascended in a balloon from Bedford, England, and when at an elevation of two miles, they got into a cloud of sleet and snow, and the balloon was quickly covered with ice. In trying the valve, above and below, it was found to be frozen. In this emergency, they applied a knife, and made an incision of twenty-four inches, in the silk. The gas issued forth in one continuous stream, and thus the aeronauts were rescued from the jaws of destruction. They descended safely."

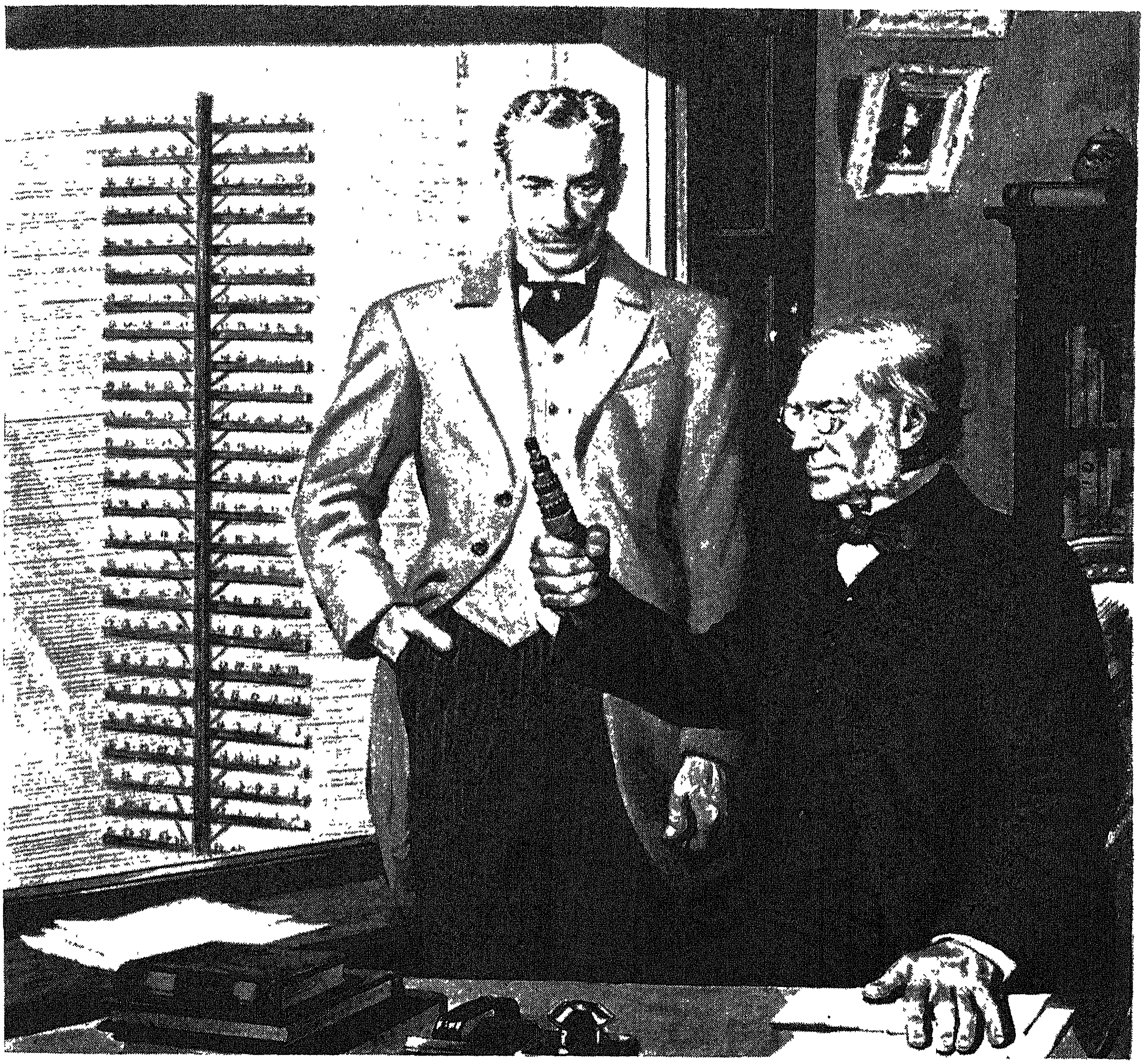
"Shortly after the brilliant discovery by Faraday of the rotation of the plane of polarization of light produced by magnetism, M. Wartmann announced that he had tried the same experiment upon radiating heat. Several persons are said to have failed in the attempt to reproduce the phenomenon, but MM. de la Prevostaye and Desains have succeeded, modifying, however, the process of M Wartmann. They fully believe that their experiments establish, beyond a doubt, the rotation of the plane of polarization of heat under the influence of magnetism."

"M De la Rive experimentally supports the hypothesis that the luminous matter of the aurora is due to the electric fluid contained in the atmosphere at great heights, where the air is rarefied. This explains, he thinks, why the magnetic pole is always the apparent centre from which the light that constitutes the aurora borealis proceeds, or towards which it seems to converge."

"By the latest news from California we learn that a Constitution has been adopted, and they are knocking for admission into the Union. Gold is still plenty, and the prospects still good, with hard work and a good chance for sickness."

"We have often thought that no city in the world could show such a rapid increase as that of New York, but a recent Parliamentary paper proves conclusively that we were very much mistaken. In ten years, from 1839 to 1849, the increase of the inhabitants of London has been 325,904; and 64,058 houses have been erected, 1,642 new streets opened, of 200 miles in length. It now numbers 2,336,960 inhabitants. What a Babel!"

"Census of the United States. 1830, 12,866,020; 1840, 17,063,353. In 1850 the population will be 23,149,309. Eighty years hence will find the population of the United States 240,000,000; quite equal to the present population of Europe, or one-fourth the population of the world."



They Packed a Pole Line Into a Pipe

Back in the eighties, telephone executives faced a dilemma The public demanded more telephone service. But too often, overloaded telephone poles just couldn't carry the extra wires needed, and in cities there was no room for extra poles. Could wires be packed away in cables underground?

Yes, but in those days wires in cables were only fair conductors of voice vibrations, good only for very short distances. Gradually cables were improved; soon every city call could travel underground, by the early 1900's even cities far apart could be linked by cable.

Then Bell scientists went on to devise ways to get more service out of the wires. They evolved carrier systems which transmit 3, 12, or even 15 voices over a pair of long distance wires. A co-axial cable can carry 1800 conversations or six television pictures. This is another product of the centralized research that means still better service for you in the future.

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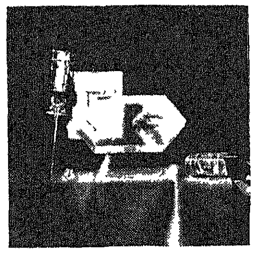

THE COVER

In the center of this month's cover painting is a crystal of ethylene diamine tartrate (EDT), the piezoelectric properties of which assist modern telephone communication (*see page 46*). This crystal, six inches long and an inch thick, is synthetically grown out of solution on a "seed," whose original outline is still visible in the right half of the crystal. From this "mother crystal" are cut rectangular slabs which are plated with gold and mounted in an assembly like that shown at the left. This assembly is the main constituent of the complete EDT crystal filter unit, shown at the right on the edge of the green baize cloth. In telephone circuits such units separate the dozens of different carrier frequencies, each carrying a different signal, that are transmitted simultaneously over one telephone cable. Each unit is tuned to a single carrier frequency, and filters out one message to be passed on to its destination. In the background is an isometric drawing of a piezoelectric crystal. Because of EDT's property of birefringence, or double refraction, there are two distinct images of each line in that part of the drawing behind the crystal. The crystals, grown at Western Electric Company's Allentown, Pa., plant, were developed as a synthetic substitute for natural quartz.

THE ILLUSTRATIONS

Cover by Walter Murch

Page	Source
11	David Stone Martin
14	Eric Mose
16	David Stone Martin
18-21	Mount Wilson and Palomar Observatories
23-24	Richard Wolters
33	Bureau of Mines, United States Department of the Interior
34	Irving Geis (*top*), Bureau of Mines, United States Department of the Interior
37-39	Irving Geis
41-43	William Auerbach-Levy
44-45	Aero Service Corporation
46-51	Eric Mose
54-56	David Stone Martin
59-60	Roger Hayward

What GENERAL ELECTRIC People Are Saying

D. E. CHAMBERS,

Research Laboratory

RESEARCH PEOPLE: The laboratory director is constantly looking first for persons of outstanding natural attributes and only secondly does he look at the scientific tools derived from training and experience which the man has collected. Of course the laboratory must achieve a balance of effort in the various fields, such as physics, chemistry, metallurgy, etc., as is deemed to be required by the Company's fields of interest, but it has been demonstrated many times that a truly outstanding man with good basic scientific training can contribute to a surprising degree in several fields.

We have found that a true research man has outstanding scientific curiosity and is primarily interested in the unknown. Obstacles challenge him, and arbitrary procedures and rules tend to irritate him. He seldom has the patience to carry a new idea through to a finished design. The exceptional is an inspiration to him, and when he finds it he seeks to develop its peculiarities to the fullest extent. His imagination is of the philosophical type, which enables him to co-ordinate his observations into hypotheses for experimental verification or disproof. He is always an optimist, for it is easy to think of many reasons why a proposed experiment would be futile; the man who makes the discoveries is the man who goes ahead and tries it; optimism is to research what vitamins are to the animal organism.

National Electronics Conference, Chicago, September 27, 1949

★

E. E. CHARLTON,

Research Laboratory

MEDICAL ELECTRONICS: Investigations of the effect of cathode rays on living tissue have been under way by various investigators for a number of years. The recent development of high-energy electron accelerators has considerablyexpanded work in this field. The penetrating power of electrons in matter increases rapidly with voltage and can thus be varied at will. In sufficient dosage they are lethal to bacteria and molds, destroy cellular tissues, deactivate enzyme systems, and in some cases produce chemical changes as well.

The field of application of electron beams directly in medicine and their potentialities can not safely be estimated today. They may give us improved techniques for the destruction of cancer cells, they may give us new and useful methods in the sterilization and preservation of some food and drug products. They may even assist in the production of new food products. In certain cases, high molecular organic molecules may, by cathode-ray exposure, be broken down into simpler ones, thus producing chemical changes difficult to achieve by conventional methods. A precursor of vitamin D has been changed by cathode rays to the active form, and it is conceivable that the precursors of hormones could be similarly changed. Plant growth may also be stimulated and some indigestible materials may, by cathode rays, be made digestible.

6th Inter-American Congress of Surgery, Chicago, October 21, 1949

★

J. R. STEHN,

Research Laboratory

AGE OF THE EARTH: A very interesting set of deductions can be made about natural and geological phenomena from the ratio of isotopes found in nature under different conditions. The age of the earth has been estimated (and this is the most accurate way known of doing it) by the measurement of the relative amounts of the different lead isotopes in samples of rocks which the geologists know to have been undisturbed since they originally solidified on the earth's crust.

Certain of these rocks originally contained uranium, and this uranium decomposed in time into its final end-products: lead-206 and lead-207. The ratios of the abundances of these isotopes of lead to that of another one of the isotopes, say lead-208, that occurs in ordinary lead (which the rock may, of course, also contain), tell what fraction of the lead now in the rocks came originally from the uranium that once must have been in the rock. Tying that in with the uranium that is still left in this same sample of rock, one can estimate what fraction of the uranium has decomposed, and this lets one estimate the age of the rock and hence of the earth. It is thus that an age of about two billion years is generally stated.

WGY Science Forum, September 21, 1949

★

H. A. WINNE

Vice President

COST OF PROGRESS: In bygone days the progress of tribes and nations could only be made at the expense of other tribes and nations—by the exploitation of their resources, by the enslavement of their peoples. Technological advances hold the possibility of progress at nobody's expense, through increasing productivity—through, in effect, greatly increasing the length and strength of every man's arm. If the world today sometimes seems to be trembling dangerously on the brink of atomic war, it might be salutary to remember, as a kind of counterbalance, that man has been struggling for survival for thousands of years, and sometimes has been pushed, or has stumbled, dangerously close to the edge, too. We are gaining, sufficient for our purposes or almost so, mastery of nature. We have left the problem of self-control, which, difficult though it may be, is still, I believe, within the possibility of man's achievement.

Newark College of Engineering, June 8, 1949

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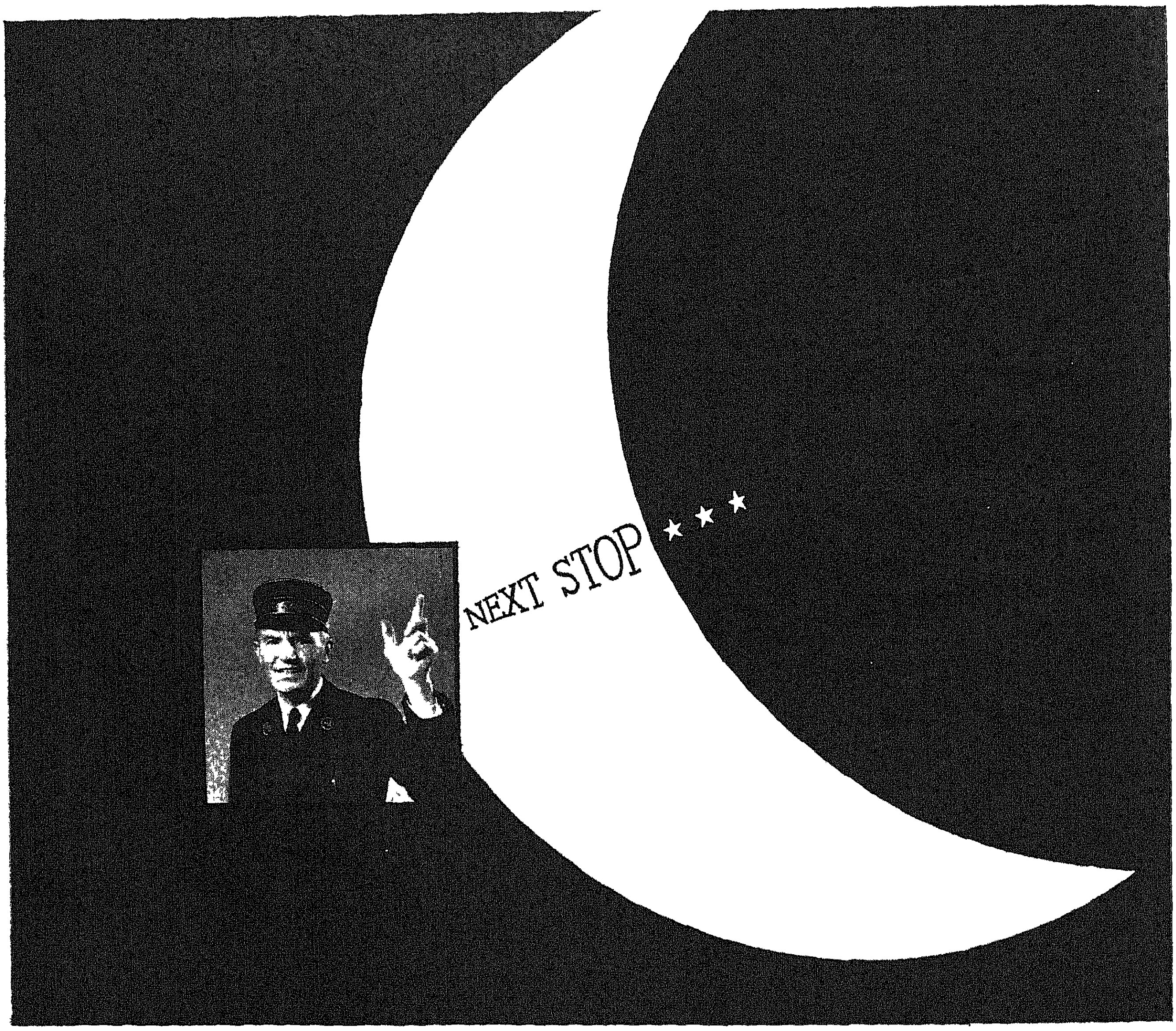
CONTENTS FOR DECEMBER 1949 VOLUME 181, NUMBER 6

ARTICLES

DEPARTMENTS



For centuries man has dreamed of the conquest of Space. In the works of Jules Verne and H. G. Wells we have had a brief, imaginative look at the excitement of interplanetary travel.

Today space travel is no longer a fantastic dream. Science and engineering have gone far beyond the technical fumblings of early writers, and it is not unlikely that in the next fifty years someone will arrive at the moon. Radio waves have already been reflected from this whistle stop in space, and in your lifetime some sort of missle will no doubt be sent there.

Much work remains to be done — nothing comparable to another Oak Ridge, however — but intelligent people are working seriously on problems of space ships and means for travel in atmospheres like the moon.

National Research has, for some time, been concerned with problems relating to space travel — problems not too far removed from many encountered in the high vacuum field. To name a few: altimeters for use above 200,000 feet, speedometers for use beyond the sonic range, gas-free metals for rockets, analysis of components of the upper atmosphere, and simulation of upper atmosphere conditions in the laboratory.

Our research organization is always interested in the development of new industrial processes or ideas, particularly those where real imagination or, in many cases, "the courage of ignorance" is required. We have accumulated a great background of experience in tackling research jobs for ourselves and other organizations, and we always welcome an opportunity to become involved with a new project that at first appears impossible to solve.

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DECEMBER 1949 VOL. 181, NO. 6

THE NOBEL PRIZES

Although they are given in literature and peace as well as science, they have mainly reflected a scientific age. A history of the science prizes and how they were begun

by George W. Gray

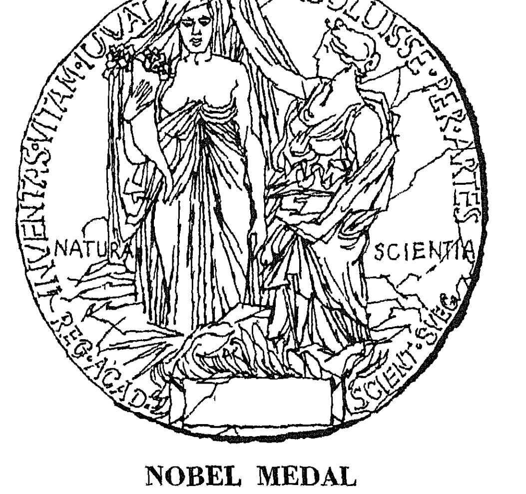
NO one knows what chain of events shaped the munificent will of Alfred Nobel, but it seems likely that the Nobel prizes owe their genesis to an advertisement which appeared, unsigned, in the Vienna *Neue Freie Presse* in 1876:

"Elderly, cultured, wealthy gentleman requires equally mature lady, linguist, as secretary and supervisor of household in Paris."

This want ad briefly brought into Alfred Nobel's household a lady named Bertha Kinsky, who was to exercise a determining influence upon him. Although she served as his secretary only a few days, then eloping to Vienna for marriage with young Baron von Suttner and journeying eastward to a distant home beyond the Black Sea, Nobel conceived an immediate admiration for her which their separation never diminished. The Dynamite King wrote many letters to "My dear Baroness and Friend." Even when she became a vigorous apostle of pacifism in the 1880s, Nobel, then chief explosives munitioner to the armies of Europe, responded warmly. When Bertha's propaganda novel *Lay Down Arms* was published in 1889, he wrote her an enthusiastic letter of congratulation. "The charm of your style and the grandeur of your ideas," he glowed, "are now and will always be carrying much farther than all the Labelles, Nordenfeldts, de Banges, and other tools of Hell."

These benevolent words did not mean that the man who made the smokeless powder that powered the Nordenfeldt guns was ready to come out for disarmament. Nobel, who all his life professed hatred of war, had a different formula: peace through frightfulness. In the first week of their acquaintance, he had said to Bertha. "I wish I could invent a substance or a machine with such capacity for destruction that wars would thereby become altogether impossible." Years later, when they were strolling along the shore of Lake Zurich and Bertha twitted him about his "dynamite factories," Nobel retorted: "Perhaps my factories will end war sooner than your peace congresses."

It was, however, during this same 1892 meeting at Zurich, where the von Suttners were Nobel's guests, that the Nobel prizes got their start. At dinner one day the munitions maker challenged the Baroness: "Inform me, convince me; then I will do something great for the movement." She was quick to seize the



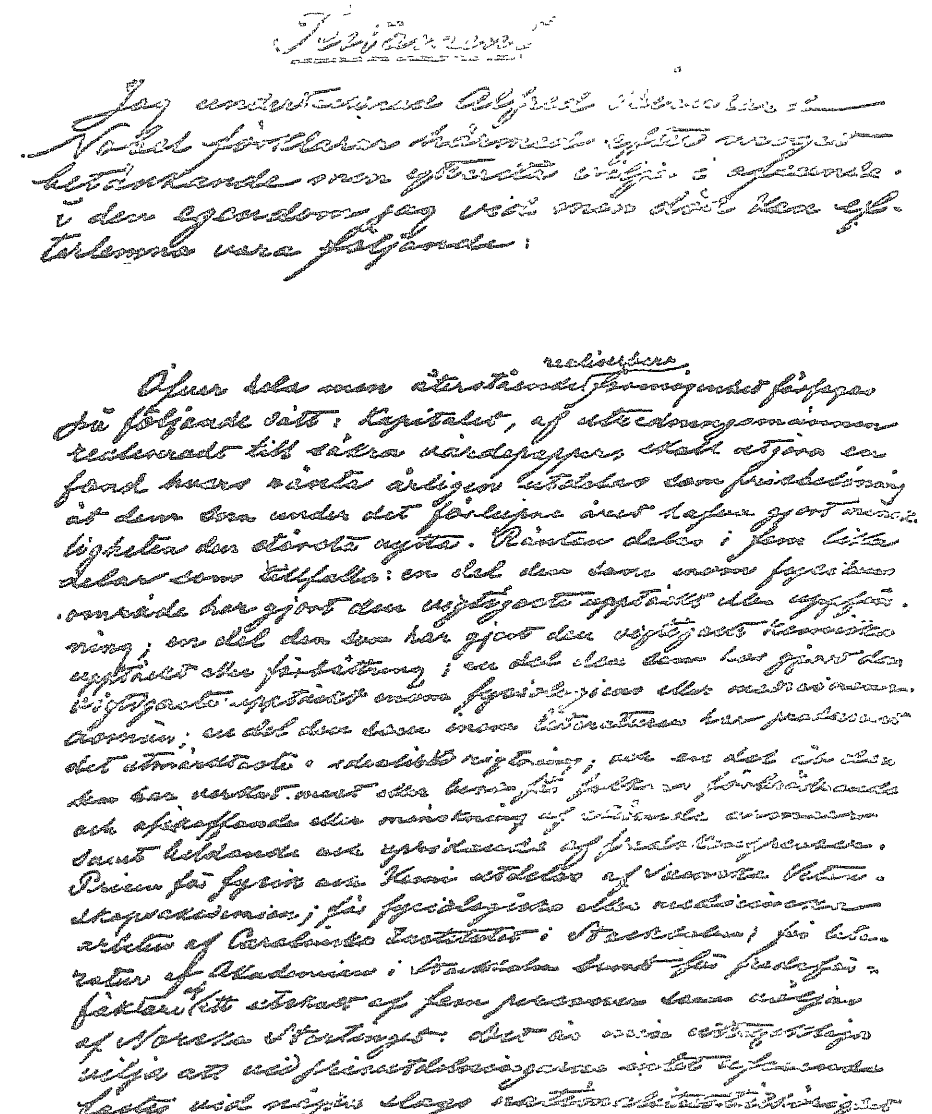
NOBEL MEDAL

THE NOBEL PRIZES IN SCIENCE FOR 1949

Physics: To Hideki Yukawa, Japanese theoretical physicist, now a visiting professor at Columbia University, "for his prediction of the existence of the meson, based upon his theory of nuclear forces." Dr. Yukawa is 42.

Chemistry: To William Francis Giauque, Canadian-born physical chemist at the University of California, "for his contribution to chemical thermodynamics, especially for his investigations of the properties of substances at extremely low temperatures." Dr. Giauque is 54.

Physiology and Medicine: One half to Antonio Caetano de Abreu Freire Egas Moniz, professor emeritus of neurology at the University of Lisbon, principally for his development of the psychosurgical operation prefrontal lobotomy. Dr. Egas Moniz is 75. One half to Walter Rudolf Hess, director of Zurich University's Physiological Institute, "for his discovery of the functional organization in the diencephalon [between-brain] for coordination of the activity of internal organs." Dr. Hess is 68.



Testamente

Jag undertecknade Alfred Bernhard Nobel förklarar härmed efter moget betänkande min yttersta vilja i afseende å den egendom jag vid min död kan efterlemna vara följande:

Öfver hela min återstående realiserbara förmögenhet förfogas på följande sätt: Kapitalet, af utredningsmännen realiseradt till säkra värdepapper, skall utgöra en fond hvars ränta årligen utdelas som prisbelöning åt dem som under det förlupne året hafva gjort menskligheten den största nytta. Räntan delas i fem lika delar som tillfalla: en del den som inom fysikens område har gjort den vigtigaste upptäckt eller uppfinning; en del den som har gjort den vigtigaste kemiska upptäckt eller förbättring; en del den som har gjort den vigtigaste upptäckt inom fysiologiens eller medicinens domän; en del den som inom litteraturen har producerat det utmärktaste i idealisk rigtning; och en del åt den som har verkat mest eller bäst för folkens förbrödrande och afskaffande eller minskning af stående armeer samt bildande och spridande af fredskongresser. Prisen för fysik och kemi utdelas af Svenska Vetenskapsakademien; för fysiologiska eller medicinska arbeten af Carolinska Institutet i Stockholm; för litteratur af Akademien i Stockholm samt för fredsförfäktare af ett utskott af fem personer som väljas af Norska Stortinget. Det är min uttryckliga vilja att vid prisutdelningarne intet afseende fästes vid någon slags nationalitetstillhörighet sålunda att den värdigaste erhåller priset antingen han är Skandinav eller ej.

Detta testamente är hittills det enda giltiga och upphäfver alla mina föregående testamentariska bestämmelser om sådana skulle förefinnas efter min död.

Slutligen anordnar jag såsom varande min uttryckliga önskan och vilja att efter min död pulsådrorna uppskäras och att sedan detta skett och tydliga dödstecken af kompetente läkare iakttagits liket förbrännes i s.k. krematorium.

Paris den 27 November 1895

Alfred Bernhard Nobel

NOBEL'S WILL was drafted in his own hand on November 27, 1895. Most of it deals with the prizes (*see text of article*). The last paragraph reads: "It is moreover my express will and injunction that my veins shall be opened after my death, and that when this has been done, and competent doctors have noted signs of my death, my body shall be burned in a crematorium."

opportunity, but after days of dueling with the wit and hardheaded skepticism of her host, Bertha went home feeling that she had failed. The following January, however, came a surprising New Year's letter from Nobel:

"I should like to allot part of my fortune to the formation of a prize fund to be distributed in every period of five years (we may say six times, for if we have failed at the end of 30 years to reform the present system we shall inevitably revert to barbarism). This prize would be awarded to the man or woman who had done most to advance the idea of general peace in Europe. I do not refer to disarmament, which can be achieved only by slow degrees. I do not even necessarily refer to compulsory arbitration between nations, but what I have in view is that we should soon achieve the result—undoubtedly a practical one—that all states should bind themselves absolutely to take action against the first aggressor. . . ."

Three months later, on March 14, 1893, Nobel drafted the first version of his will. It left his residuary estate to the Royal Academy of Science at Stockholm, directing that the Academy make an annual distribution of the income "as a reward for the most important discoveries or achievements in the wide field of knowledge and progress, excluding physiology and medicine." The will commended for special consideration "such persons as are successful in combatting by word and deed the peculiar prejudices still cherished by peoples and governments against the inauguration of a European peace tribunal."

No one knows why this will departed so far from the plan outlined in his New Year's letter to Bertha, what decided him to offer an unspecified number of prizes for contributions in a wide field instead of one prize for the advancement of peace. At all events, the ailing, aging millionaire, who had now retired from active management of his vast business scattered over eight countries, soon began to worry about his will. Perhaps it was too loose, not sufficiently specific. He regretted excluding physiology and medicine. He resolved to write a new will. Despite a severe heart ailment, he journeyed from his San Remo villa in northern Italy to the Swedish Club in Paris and, disdaining lawyers, as he did physicians, he composed the document himself. Four of his cronies at the Swedish Club witnessed his signature on November 27, 1895, and he carried the paper back to San Remo. The heart attacks increased in intensity. On December 10, 1896, he collapsed at his desk.

Bertha learned of his death, as she had met him 20 years before, through a newspaper. The obituaries all carried surmises as to how Nobel had disposed of his millions, with hints of great humanitarian projects, but nobody knew

the actual contents of the will until it was opened a few days after the funeral

Nobel's Will

When the will was read, it made headlines all over the world. After some minor bequests to relatives and others, Alfred Nobel directed that the residue of his estate be invested in safe securities, and that the interest accruing from this capital *be awarded annually in prizes to those persons who shall have contributed most materially to benefit mankind during the year immediately preceding The said interest shall be divided into five equal amounts to be apportioned as follows.*

One share to the person who shall have made the most important discovery or invention in the domain of Physics,

One share to the person who shall have made the most important Chemical discovery or improvement;

One share to the person who shall have made the most important discovery in the domain of Physiology or Medicine,

One share to the person who shall have produced in the field of Literature the most distinguished work of an idealistic tendency,

And, finally, one share to the person who shall have most or best promoted the Fraternity of Nations and the Abolition or Diminution of Standing Armies and the Formation and Increase of Peace Congresses.

The will asked the Royal Academy of Science to be responsible for selecting the winners in physics and chemistry, the Karolinska Institute of Medicine in Stockholm to do the selecting in physiology and medicine, the Swedish Academy (of Letters) to choose the winners in literature, and a committee of the Norwegian Parliament to award the peace prize. It specified that in awarding the prizes "no consideration whatever be paid to the nationality of the candidates."

It was magnificent—and breath-taking. "Could we have believed that Mammon, Mammon sprung from dynamite, should be so ennobled?" wrote a Paris correspondent. The scope of the benefaction was unprecedented. The Cecil Rhodes scholarships, the Rockefeller and Carnegie Foundations and other large international philanthropies were still in the future. Universities and learned societies had long given prizes for the encouragement and reward of intellectual achievement, but never on such a lavish scale or with such broad eligibility. Alfred Nobel was truly a trail blazer when he composed his last will.

His Swedish nephews and nieces, children of his deceased brother Robert, who had been left a puny £5,000 each, brought suit to break the will. The lawsuit never came to trial. It was settled out of court by a stipulation that granted the Swedish heirs "certain pecuniary advantages" which were never made public but were understood to be substantial. Beyond this opposition within the family, there was powerful opposition from the conservative element in Swedish politics, including some members of the Government who were suspicious of Norway.

There were other problems. It is a pity that Nobel did not call in a lawyer to draft the will. Although to a layman Nobel's intentions would seem clearly expressed, a legal mind could point to many ambiguities, loopholes and omissions, any one of which might provide an opening for litigation For example, to whom was the residuary estate willed? The academies, institute and parliament were empowered to select the prize winners, but who was to hold the huge trust fund and manage its investment over the years? What specific criteria were to be applied in selecting the prize winners? Altogether more than three years were consumed in the delicate negotiations, public hearings and legal red tape that were necessary to bring the various interests to agreement and embody this in a code of statutes. Finally, in June of 1900, all disputes had been ironed out, the code of statutes was confirmed by King Oscar II, and the Nobel Foundation began to function as the holder of Nobel's legacy and the administrator of his intentions.

By that time the legacy had been somewhat diminished. In addition to the money paid the Swedish heirs, millions of kroner had been spent in lawyers' fees and other expenses. For the Foundation and the prizes there remained 27,716,243 kroner, equivalent to $7,427,953. This does not seem a large fortune by present-day standards, but in 1900 it was enormous. The thrifty Swedes were shocked by the thought that the interest on this amount was to be distributed among only five persons. It was incredible, many argued, that Nobel could have intended to distribute such extravagant prizes. But one of his close friends, an associate who had witnessed the signing of the will, declared under oath. "His desire was, as he always stated, to place those whose work showed promise in a position of such complete independence that they would be able to devote their whole energies to their work."

Nobel's Intentions

It will always be a moot question how closely the distribution of the Nobel prizes has conformed to Alfred Nobel's intentions. Some of his stipulations admittedly were difficult, if not impossible, to fulfill. He specified that each prize be given in recognition of services rendered during the previous year—but who is omniscient enough to know which of the workers in physics, chemistry and biology "contributed most materially to benefit mankind during the year immediately preceding"? A discovery in science usually takes from two to 10 years, sometimes longer, to prove its value. It was finally agreed, in the code of statutes, that the qualification "during the year immediately preceding" was to be interpreted as meaning that works of earlier years whose importance had just been demonstrated were also to be considered.

The first Nobel prizes were awarded in 1901 During the preceding year Max Planck had published his revolutionary quantum theory, in 1898 Pierre and Marie Curie had discovered radium; in 1897 J J. Thomson had discovered the electron, in 1896 Henri Becquerel had discovered radioactivity. But for the first Nobel prize in physics the Swedish Royal Academy of Science chose none of these, it went back to an earlier discovery and made the award to Wilhelm K. Rontgen for his discovery of X-rays in 1895. Historians will probably agree that it was fitting for the first award to go to Röntgen, for his X-rays were the cock's crow of the revolution in physics. His discovery spurred Becquerel to renewed experiments with uranium, illuminated Thomson's search for the electron and contributed importantly both to the Curies and to Planck. (All these persons eventually received Nobel prizes—Becquerel and the Curies in 1903, Thomson in 1906, Planck in 1918) In naming Röntgen, the prize-givers recognized the opening discovery in the brilliant sequence of findings that overturned classical physics—the first step in the fateful march to our Atomic Age.

The other 1901 Nobel prizes in science were for works of even older vintage. J. H. van't Hoff received the chemistry prize for discoveries in chemical thermodynamics and osmotic pressure which he had made in the 1880s; E. A. von Behring was awarded the prize in physiology and medicine for his antitoxin against diphtheria, discovered 10 years before. Indeed, in the whole history of the Nobel science prizes there is just one instance of an award for a contribution of the previous year. the prize in physiology and medicine awarded jointly to F. G. Banting and J. J. R. Macleod in 1923 for the discovery of insulin, which they and their co-workers, C. H. Best and J. H Collip, had announced in 1922. Usually the Nobel accolade has been given for achievements five to 10 years old. The average age of the winners in science has been: physics, 46 years; chemistry, 49; physiology and medicine, 54. Sir Charles Sherrington was 71 years old and Thomas Hunt Morgan 79 when prizes were awarded them.

This brings up a question. Was it Alfred Nobel's intention to reward great figures who had already arrived, or was he primarily concerned with encourag-

YEAR	PRIZE	LAUREATE	INSTITUTION
1907	Physics	A A Michelson	University of Chicago
1912	Physiology	Alexis Carrel	Rockefeller Institute
1914	Chemistry	T W Richards	Harvard University
1923	Physics	R A. Millikan	California Institute of Technology
1927	Physics	A H Compton (one half)	University of Chicago
1930	Physiology	Karl Landsteiner	Rockefeller Institute
1932	Chemistry	Irving Langmuir	General Electric Laboratories
1933	Physiology	T H Morgan	California Institute of Technology
1934	Physiology	G H Whipple (one third)	University of Rochester
1934	Physiology	G R Minot (one third)	Harvard University
1934	Physiology	W. P Murphy (one third)	Harvard University
1934	Chemistry	H C Urey	Columbia University
1936	Physics	C D. Anderson (one half)	California Institute of Technology
1937	Physics	C J Davisson (one half)	Bell Telephone Laboratories
1939	Physics	E O. Lawrence	University of California
1943	Physiology	E. A Doisy (one half)	St. Louis University
1943	Physics	Otto Stern	Carnegie Institute of Technology
1944	Physics	I. I Rabi	Columbia University
1944	Physiology	Joseph Erlanger (one half)	Washington University
1944	Physiology	H S Gasser (one half)	Rockefeller Institute
1945	Physics	Wolfgang Pauli	Institute for Advanced Study
1946	Physics	P. W. Bridgman	Harvard University
1946	Chemistry	J B. Sumner (one half)	Cornell University
1946	Chemistry	J H. Northrop (one fourth)	Rockefeller Institute
1946	Chemistry	W. M. Stanley (one fourth)	Rockefeller Institute
1946	Physiology	H. J. Muller	University of Indiana
1947	Physiology	C F Cori (one fourth)	Washington University
1947	Physiology	Gerty Cori (one fourth)	Washington University
1949	Chemistry	W. F. Giauque	University of California

GRAND TOTAL

124 PRIZES
158 PERSONS
20 COUNTRIES

	PHYSICS		CHEMISTRY		PHYSIOLOGY		TOTALS	
	Prizes	Persons	Prizes	Persons	Prizes	Persons	Prizes	Persons
Germany	10	12	16½	18	7	8	33½	38
U. S.	8½	10	5	7	7	12	20½	29
Great Britain	9½	12	6	7	4½	9	20	28
France	4	6	4	6	3½	4	11½	16
Sweden	2	2	4½	5	1	1	7½	8
Netherlands	3	4	1	1	1½	2	5½	7
Switzerland	1	1	2	3	2½	3	5½	7
Denmark	1	1			3½	4	4½	5
Austria	½	1	1	1	2½	3	4	5
Italy	1½	2			½	1	2	3
Belgium					2	2	2	2
Canada					1	2	1	2
Finland			1	1			1	1
Hungary					1	1	1	1
India	1	1					1	1
Japan	1	1					1	1
Russia					1	1	1	1
Argentina					½	1	½	1
Portugal					½	1	½	1
Spain					½	1	½	1

MANY COUNTRIES have shared the prizes in science. A list of U. S. winners is given at the top of this page. The distribution of prizes among all countries is at the bottom. Although a number of foreign-born winners are credited to the U. S., the 1949 prize of Columbia's visiting professor Yukawa has here been credited to Japan.

ing young scientists of unusual brilliance and achievement? We recall the statement by a witness to the will that Nobel's desire was to place those whose work showed promise in a position of independence; another witness reported that Nobel once remarked: "I would not leave anything to a man of action, since he would be tempted to abandon work. On the other hand, I would like to help dreamers, for they find it hard to get on in life." It would be interesting to check the list to see how many awards have gone to dreamers who were finding it hard to get on in life. Perhaps Hermann J. Muller might have qualified 20 years ago when he had just discovered the effect of X-rays in inducing genetic mutations and was laboring on a meager University of Texas salary to extend his experiments. Within five years Muller's discovery opened up a new chapter in the study of genes. But no Nobel committee of award looked his way during those years of struggle, and he carried his dream from Texas to the U.S.S.R., and then, disillusioned, was a refugee in Scotland for three years before a research post was found for him in the U. S. At last in 1946, in his 56th year and a few months after he had been appointed a professor at the University of Indiana, the Nobel authorities decided that the work he had done in Texas in 1926 deserved a prize.

It must be admitted that the difficulty of picking the youthful dreamers who are going to benefit mankind is enormous. Moreover, dreamers are not permitted to submit their dreams in application for a prize. "A candidate for a prize must be proposed in writing by some duly qualified person," says the code of statutes. "A direct application will not be taken into consideration." The list of duly qualified persons designated as competent to nominate candidates includes members of the academy that awards the prize, former Nobel prize winners, certain professors in Scandinavian universities, and selected persons in outside countries. The latter are appointed for 12 months, so there is a new group each year. To assist in selection of the 1949 winner in physics, 237 scientists outside of Sweden, including 42 in the U. S., were invited to propose candidates. In chemistry, the corresponding figures are 285, with 42 from the U. S.; and in physiology and medicine, some 700, of whom 200 are Americans.

Sharing the Prizes

The youngest person to receive a Nobel award was William Lawrence Bragg, who was only 25 in 1915 when the prize in physics was awarded jointly to him and his world-famous father, Sir William Henry, for the ingenious measurements of the wavelength of X-rays in which the father and son collaborated. Next youngest were P. A. M. Dirac, Carl D. Anderson and Werner Heisenberg, who became laureates at the age of 31. Of these only Heisenberg got a full prize. Dirac was awarded the prize in physics jointly with Erwin Schrodinger, who was 46, and Anderson shared his with Victor F. Hess, 53.

There is nothing in the will to indicate that Alfred Nobel intended a prize to be split. The testament plainly directs that the annual income is to be divided into five equal shares, and that one share is to be given to each of five persons. The idea of dividing a prize originated with the Swedish nephews and nieces who tried to break the will and compromised on an out-of-court settlement. In this settlement they stipulated, among other provisions, that "in no circumstances should a prize be divided into more than three prizes." The prize-awarders have frequently taken advantage of this permissive stipulation. Nine of the prizes in physics, six in chemistry and 12 in physiology and medicine have been split among two or three persons.

This sharing of the prizes has not seriously discommoded anyone. The money value of an award, which varies from year to year according to the income from the capital, ranges between $30,000 and $40,000, and even a third of that is a substantial reward. Moreover, while the money may be fractionated, the honor is not. No one is ever described as a one-third Nobel prize winner.

The idea of joint awards is entirely consistent with the method as well as the history of science, since no scientist works alone, but each is part of an international whole. Often, as in the case of the Braggs, more than one person was directly responsible for the work rewarded. Sometimes a result by one scientist hinged on an earlier achievement by another. Thus George H. Whipple's experiments with anemia in dogs provided the basis for George R. Minot's experiments with liver therapy in the treatment of pernicious anemia in human beings, recognizing this interdependence, the Karolinska Institute awarded the 1934 prize in physiology and medicine jointly to Whipple, Minot and Minot's assistant, William P. Murphy.

Inventors and Discoverers

Alfred Nobel was an inventor; he held patents on more than 300 inventions besides dynamite, smokeless powder and the detonator. He specified that the prize in physics should be given for "discovery" or "invention," and the prize in chemistry for "discovery" or "improvement"; only the prize in physiology and medicine was restricted to "discovery." It is only natural, however, that the basic discoveries of knowledge from which inventions flow have attracted the major attention of the committees of award. The inventors awarded Nobel prizes have been few: Guglielmo Marconi and Carl F. Braun for inventions in the field of radio, C. T. R. Wilson for his cloud chamber, E. O. Lawrence for his cyclotron, Fritz Haber for his nitrogen-fixation process; Carl Bosch and Friedrich Bergius jointly for extending and exploiting Haber's process. All these were brilliant achievements; but if you were asked to list the most important inventions of the last half-century in the order of their service to mankind, would you put any one of them at the head of the list? It seems to me that two contributions in the domain of physics in the 20th century tower above all others. They are the invention of the airplane and the discovery of atomic energy. Harold C. Urey has said that to find human achievements comparable in importance to these it is necessary to go back to prehistoric times—to the invention of the wheel and the boat and to the discovery of fire. Atomic energy was recognized by the award of a Nobel prize to Otto Hahn in 1944 for the discovery of nuclear fission, but the inventor of the airplane went to his grave uncrowned.

The Missing

The roster of Nobel laureates is studded with the names of great and deservedly illustrious persons—some dreamers, some men of action, a few true geniuses—but there are giants missing from the list. For example, the most fundamental contribution to the physical sciences that has come out of America was the work of J. Willard Gibbs, professor of mathematical physics at Yale University during the last quarter of the 19th century. Gibbs had no laboratory; he performed no experiments; his only tools were paper and pencil, a piece of chalk and a blackboard at which he worked out his mathematical formulas. Between 1873 and 1878 he produced a series of papers on the application of thermodynamics to chemical phenomena which revolutionized the science. He is the father of physical chemistry. The phase rule which he discovered became in a few years one of the most powerful tools of chemical research and engineering. The work of Wilhelm Ostwald, of Haber, of Bosch and Bergius, each of whom received a Nobel prize, was based directly on the application of Gibbs' concepts; indeed, the very first Nobel prize in chemistry went to a follower (van't Hoff) in the field that Gibbs had pioneered. It seems an egregious error of judgment that the Nobel prize-givers, whose later choices included men both older and less distinguished than this "Newton of chemistry," passed him by.

Most of the Nobel prizes in science have been given for the discovery of a

ALFRED BERNHARD NOBEL wrote his close friend Baroness von Suttner (*below*): "I should like to allot part of my fortune to... the man or woman who had done most to advance the idea of general peace in Europe."

BARONESS VON SUTTNER, who as Bertha Kinsky had served as Nobel's secretary for only a few days, greatly influenced him in later years. She was a pacifist who in 1889 wrote a propaganda novel called *Lay Down Arms.*

particular phenomenon, particle, ray, hormone, vitamin, antitoxin, or for the recognition of new behavior in already known phenomena. There is another kind of research result which is more fundamental, more difficult to arrive at, and therefore less frequent. This is the discovery of the laws or principles which unite many phenomena under one generalization. Gibbs' law of chemical thermodynamics is of this kind: it brought about the marriage of physics and chemistry. Einstein's theory of relativity is another brilliant example of generalization; yet when the Nobel authorities chose Albert Einstein to receive the 1920 prize in physics, they made no mention of relativity but specified that the award was given "in particular for his discovery of the law of the photoelectric effect."

One of the great generalizations of modern physiology is the principle of homeostasis, and mention of the word instantly calls to mind Walter B. Cannon. This Harvard professor of physiology was the first to recognize the self-balancing mechanism of nerves and internal secretions, and he gave it its name His generalizations put the functions of the sympathetic nervous system together into a coherent and understandable scheme. While Cannon focused his laboratory studies on the sympathetic nervous system, Otto Loewi at the University of Graz, in Austria, was investigating the action of the parasympathetic nerves, and Sir Henry Dale at the University of London was exploring the transmission of nerve impulses to the skeletal muscles. It seems a strange case of judicial myopia that when the prize in physiology and medicine was awarded jointly to Loewi and Dale in 1936 for "their discoveries relating to chemical transmission of nerve impulses," Cannon's equally important work in this field was ignored.

No mathematician has received a Nobel prize, although mathematics is fundamental to physics and chemistry, and is now in process of being applied to physiology. Nor has the honor ever gone to an astrophysicist—and surely astrophysics is a part of physics. Among the mathematicians who lived and worked well into the 20th century, Henri Poincaré of France and George Birkhoff of the U. S. were unquestionably of Nobel stature. Among astrophysicists, the work of Johannes Kapteyn, Willem de Sitter, Edward Pickering and George Ellery Hale was of a character to place them among the immortals

Despite these omissions, the series of Nobel awards portrays as in a grand panorama the past half-century of physics, chemistry and biology. The work of scientists is so interrelated that the names chosen automatically suggest the missing ones. Checking over the list of the 154 persons who have received or shared in

a Nobel science prize, one is impressed with the steady, almost continuous advance of knowledge, and with the magnificence of the total achievement. From its contemplation there arises a sense of grandeur.

I have ventured no comment on the awards in literature and in peace. Such appraisal calls for the specialized resources of the literary critic and the political scientist. But one observation seems clear: whereas in science the task is complicated by the abundance of eligible candidates, in literature and peace the problem seems to be just the opposite, a scarcity. As Gilbert Murray said a dozen years ago, comparing the laureates in science with those in literature, "This age is clearly better at science than at poetry." Then he added, "In the list of peace prizes, the first thing that attracts attention is the number of times in which it could not be awarded at all."

National Scores

From the first year, when Rontgen and von Behring received the awards in physics and physiology, Germany has held the lead in the number of Nobel prizes; several times it has won two and twice three in a single year. The Kaiser took a keen personal interest and saw to it that German achievements were brought to the attention of the Nobel committees. (It is said that Emperor Wilhelm thought of himself as a suitable candidate for the peace prize, and was enraged to learn that his cousin Czar Nicholas II had been considered while he was ignored.) Even during the Nazi period of intellectual decadence—when Hitler, raging against the "insulting" award of the peace prize to a prisoner in one of his concentration camps, forbade German citizens thereafter to accept Nobel awards—German scientists continued to attract the favorable notice of the Nobel judges. Including the literature and peace awards, Germans won 40½ prizes, shared among 46 persons, through 1948. The U. S. stands second, with 30½ prizes distributed among 41 persons and one organization, the American Friends Service Committee.

Three of the Germans declined their prizes because of Hitler's ban on Nobel awards. They were Richard Kuhn (chemistry, 1938), Adolf Butenandt (chemistry, 1939) and Gerhard Domagk (physiology and medicine, 1939). Shortly after the war, Dr. Domagk wrote the Karolinska Institute a letter of explanation and apology, and the Institute gave him the diploma and medal which regularly accompany a prize. It was unable to give him the money, because the code of statutes provides that if a laureate renounces the prize or fails to claim it within 10 months, the amount shall revert to the Nobel Foundation's capital fund. Drs. Kuhn and Butenandt expressed their regrets to the Royal Academy of Science last December, and they too got medals and diplomas.

It is customary to account a Nobel prize to the nation in which the winner is a resident at the time of the award. Thus Germany is credited with the chemistry prize given Peter J. W. Debye in 1936, although Dr. Debye was born and educated and did much of his research work in Holland; he was director of one of the Kaiser Wilhelm Institutes in Germany at the time of his Nobel award. Britain gets credit for the 1945 award in physiology and medicine to Ernst B. Chain, a refugee from Germany who was working at Oxford when named for the prize. The U. S. list also includes a refugee, Wolfgang Pauli of Austria, who received the 1945 prize in physics while he was a member of the Institute for Advanced Study at Princeton. Elie Metchnikoff always rated himself a Russian, but he was director of the Pasteur Institute in Paris when the physiology prize came his way, and it was credited to France. The only other Russian to receive a science prize was Ivan Pavlov, distinguished investigator of the conditioned reflex.

The standing of the nations in the science awards and the complete list of U. S. winners in science are on page 14. The most striking point about the U. S. list is the acceleration of awards to Americans in recent years. In the first 16 years of the Nobel prizes, only three scientists in the U. S. received awards; during the next 16 years there were four; but in the past 16, ending in 1948, there were 20. In 1946 all three prizes in science went to the U. S. Moreover, many Nobel laureates of other countries have moved to America, among them Einstein, Hess, Debye, Enrico Fermi, James Franck and Otto Meyerhof. More Nobel prize winners are now resident in the U. S. than in any other country.

The Foundation

The code of statutes which governs the Nobel Foundation's administration of Alfred Nobel's legacy requires that one tenth of the annual income be added to capital. It also specifies that prize money which lapses, due to failure of the laureates to accept or of the judges to award prizes, must revert to the main fund and be invested as income-bearing capital. In this way the $7,427,953 with which the Nobel Foundation began business in 1900 has grown in 49 years to $9,900,-520.

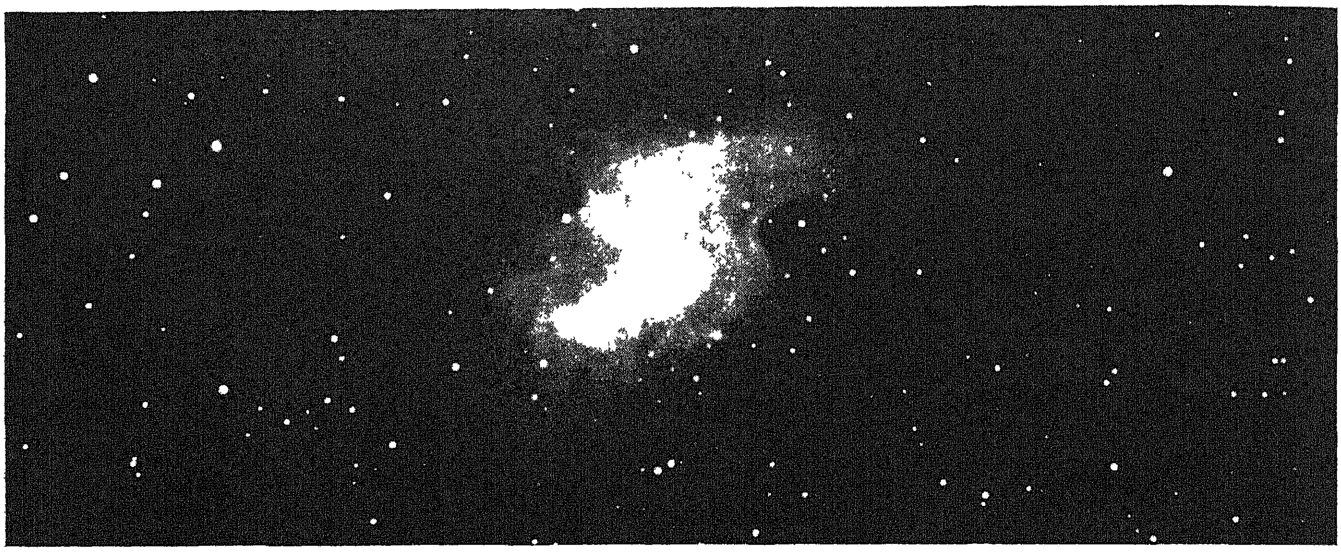
Income from this fund not only provides the five Nobel prizes and pays the expenses of administration and selection but also supports three Nobel Institutes, established "as an assistance in the investigations necessary for making their awards, and for the promotion in other ways of the aims of the Foundation." They are the Institute of Physical Sciences, which serves the Royal Academy of Science, the Institute of Biology, connected with the Karolinska Institute, and the Nobel Peace Institute in Norway. The scientific Institutes carry on active programs of research, thus the Nobel fortune not only rewards researchers for past achievements but also supports current work in its own Institutes.

The Nobel Foundation, coordinating agency for all these activities, occupies a building of six stories on the Sturegatan in Stockholm. It is governed by a five-man board of control, consisting of one member appointed by the King of Sweden and one by each of the four agencies that select the prize winners. King Gustavus V of Sweden from the beginning has taken a lively interest in the Nobel prizes, as indeed have all Swedes and most of the Scandinavian people. The annual turning of all eyes toward these northern countries for their judgment on the earth's great is a matter of understandable pride to them.

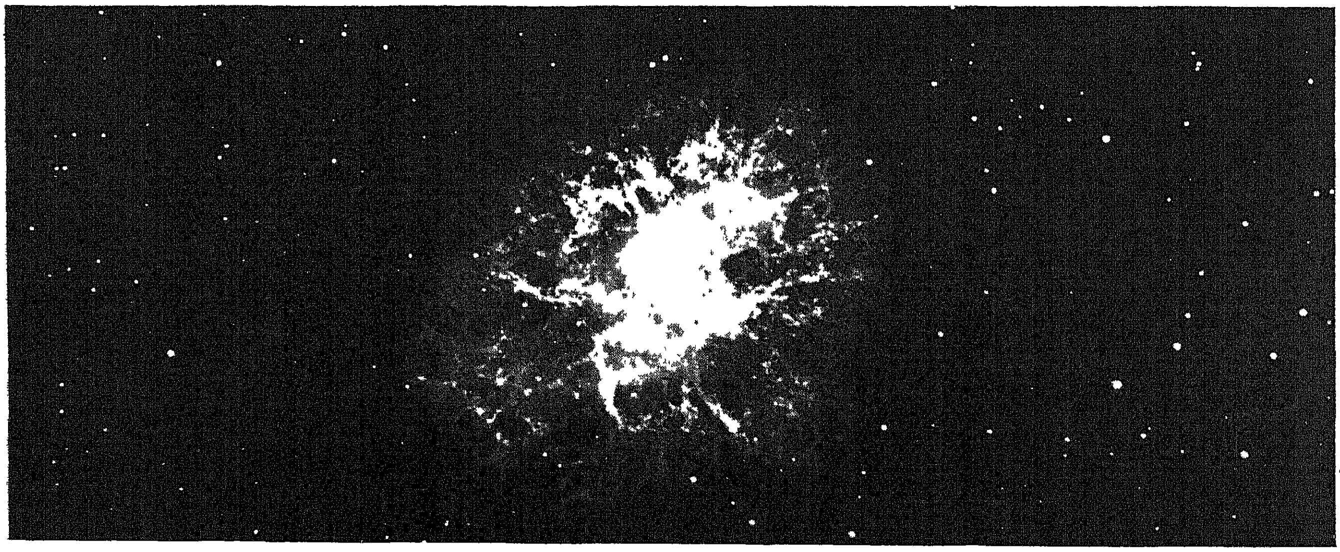
No recurrent event in the intellectual world is so avidly awaited by so many people as the annual announcement of the Nobel awards; no formal honor conferred by man carries such distinction as a Nobel prize. The awards are presented on the 10th of December, the anniversary of Alfred Nobel's death. The peace prize is given at a formal ceremony in Oslo; the physics, chemistry, physiology and medicine and literature prizes in Stockholm. At the latter ceremony the King of Sweden personally delivers to each of the winners his reward—a diploma, a gold medal and a certified check for the prize money in Swedish kroner.

It is doubtful that Alfred Nobel, were he living, would attend this ceremonial affair in the Stockholm Concert Hall. A shy, nervous man, he shrank from participating in formal gatherings. Although he usually wore the red rosette of the Legion of Honor in the lapel of his black frock coat, he always ridiculed decorations and honors. On one occasion he said, "I owe my Swedish Order of the North Star to my cook, whose skill won the approval of an eminent stomach." He avoided publicity, invariably refused to be interviewed by the press, and despised self-advertisement. Yet surely no other man in modern times has raised so wide-known a memorial to himself. Year after year, as long as civilization stands, Scandinavia's annual weighing of human achievements will serve not only to recognize and honor those who have made unusual contributions to mankind but also to remind the world of Alfred Nobel, the dreamer.

George W. Gray was the author of Cosmic Rays *and many other articles that have appeared in this magazine.*



INFRARED LIGHT (7200 to 9000 Angstroms) from the Crab Nebula records it on a photographic plate as a tenuous cloud of gas. This is apparently the remnant of a supernova observed by a Chinese astronomer in 1054.



RED LIGHT from hydrogen and nitrogen (6563, 6548 and 6584 A.) reveals the structure of those gases in the same Crab Nebula. The whole mass of gas is illuminated by a small, dense, hot star that is imbedded in it.

BLUE AND ULTRAVIOLET LIGHT (3300 to 5000 A.) show another structure of the Crab Nebula. All three of these photographs were made by Walter Baade with 100-inch Hooker telescope at Mount Wilson Observatory.

SUPERNOVAE

The medieval Chinese observed a stellar explosion that would dwarf ordinary novae. Astronomers have detected such stars in other galaxies and pondered their cause

by George Gamow

ONE clear December night about 2,000 years ago a bright star appeared on the eastern horizon—a star which had never been seen there before. It was noticed by three wise men traveling through the desert on their camels, and it led them to a barn in the little Judean village of Bethlehem. . . .

We all know and enjoy this beautiful Biblical legend, but unfortunately it lacks an important piece of information: the three wise men did not bother to measure the right ascension and declination of the new star, or to record at least its position with respect to the known constellations. Nor did they leave any information concerning subsequent changes in its brightness.

The annals of human history record several other tantalizing accounts of this kind, connecting the appearance of a new star with the coronation of some famous king, or an attack by the enemy, or a pestilence, but failing to give us the details by which we might judge whether the phenomenon was really a "new star" or, for example, a comet. We are indebted to an observant Chinese for the earliest scientific report of one of these happenings. In *History of the Sung Dynasty* we read:

"In the first year of the period *Chih-ho*, the 5th moon, the day *chi-ch'ou* [*i.e.*, July 4, 1054], a guest star appeared approximately several inches southeast of *T'ien-Kuan* [*i.e.*, Zeta Tauri]. After more than a year it gradually became invisible." In another manuscript of the same period the astronomer who noted the event reported that "the guest star was as visible by day as Venus; pointed rays shot out of it in all directions, and its color was reddish-white." He added: "Respectfully, according to the disposition of Emperors, I have prognosticated, and the result said: The guest star does not infringe upon Aldebaran; this shows that a Plentiful One is Lord, and that the country has a Great Worthy; I request that this prognostication be given to the Bureau of Historiography to be preserved." And so it was

When we point a telescope (an instrument which was, of course, unavailable to astronomers of the 11th century) at the position in the sky where the Chinese noticed this exploding star, we notice today a somewhat shapeless nebulosity with numerous tentacles reaching out into space. This diffuse object is known as the Crab Nebula. Modern photographs of the Crab Nebula taken several decades apart show that it is expanding; its diameter increases at the rate of .23 second of arc each year. Since its present diameter is about 180 seconds, by simple arithmetic we can calculate that it must have started expanding from the center some eight centuries ago, which is in reasonable agreement with the date of appearance of the Chinese "guest star." This measurement of the expansion velocity of the Crab Nebula also permits us to determine its distance from us. The amount of the Doppler shift of spectral lines emitted by the central regions of the nebulosity indicates that its gaseous masses are moving away from the center at a speed of 1,116 kilometers per second. Combining this figure with the observed rate of angular expansion, we find that the Crab Nebula is 34,000 light-years away. From the known distance, and the Chinese observer's statement that at its maximum apparent brightness the guest star was as bright as Venus, we can easily calculate that at the time of the explosion the actual brightness of the star was several hundred million times that of our sun!

Close to the center of the Crab Nebula one can notice a comparatively faint star; that is to say, it is comparatively faint at our distance, but actually it is 30,000 times brighter than our sun. This apparently is the nucleus of the star that blew up nine centuries ago, increasing in brightness from 30,000 suns to several hundred million suns. When it exploded it threw out a cloud of "smoke" which now forms the Crab Nebula.

The Crab Nebula's central star is very different from an ordinary star such as our sun. R. L. Minkowski of the Mount Wilson Observatory has calculated that its surface temperature is about 500,000 degrees Centigrade, compared with 6,000 degrees for the sun. Since the brightness per unit of a body's surface increases as the fourth power of the temperature, this means that per unit of surface the Crab Nebula star is about 50 million times brighter than the sun. Yet its total brightness is only 30,000 times greater, so the star must be much smaller than our sun—about one fortieth of the sun in radius. Assuming that the mass of the star is comparable with the sun's, its density must be several hundred thousand times greater! The mass of the gauzy nebula that surrounds the star is estimated to be 15 times that of our sun. Thus it seems that before it exploded the original star was considerably more massive than the sun, and much more than half its mass was ejected into space by the force of the explosion.

Since 1054 only two similar stellar explosions have occurred within the Milky Way. One was observed by the famous Danish astronomer Tycho Brahe in 1572; the other by his pupil Johann Kepler in 1604. Although these explosions were apparently about as powerful as that observed in 1054, they left no such impressive smoke cloud as the Crab Nebula. Near the position of Kepler's "stella nova" we now observe some irregular patches of luminous gas, but they are obscured by heavy dust clouds in interstellar space. Of Tycho Brahe's star we can see no visible remnants at all. There is hardly any doubt, however, that each of these explosions threw out about as much "smoke" as in the Crab Nebula. In all likelihood the reason we do not see the nebulae so clearly is that the central stars illumine them less strongly.

THESE giant stellar explosions, or supernovae, apparently occur every three or four centuries in our galaxy. The time is just about ripe for another one. We need not wait with folded hands, however, until the next star in the Milky Way decides to blow up. In the billions of galaxies scattered through the vastness of space supernovae are exploding all the time. Though these distant explosions are not visible to the naked eye, they show up clearly enough in telescopes In 1885 such an explosion

was observed in our nearest neighboring galaxy, the Great Nebula in Andromeda.

To detect at least one supernova per year, we would have to keep several hundred galaxies under constant surveillance. Work in this direction was started more than a decade ago by W. Baade and F. Zwicky at the Mount Wilson Observatory. They collected a bag of three big explosions in the very first year. One of these, photographed in the spiral nebula known as IC 4182 in late August, 1937, is shown on the opposite page. We are now in possession of the records of a number of supernovae, from which curves have been plotted showing their luminosity changes from the time of maximum brightness until they finally disappeared from sight. We also have very extensive information concerning the spectral changes in the emitted light during the various stages of the explosion.

But, and this is a very serious but, our observations can give us little or no direct information about the nature of the physical processes that produce these spectacular flare-ups. The appearance of any explosion essentially depends only on the amount of liberated energy, and not on the particular way in which this energy is liberated. An astronomer who tries to guess how a star explodes is in the same position as a chemist would be if he tried to guess the chemical composition of a shell by watching it burst in the air, or a physicist if he tried to reconstruct the secret mechanism of an atomic bomb after seeing one mushroom into the atmosphere.

So we must content ourselves with considering various hypotheses and accepting the one that seems to be most consistent with the known properties of the interiors of the stars and with the physical processes which are likely to take place under the conditions of extremely high temperatures and pressures existing in them.

TO begin with, it is important to note the distinction between these giant explosions, or supernovae, and the less spectacular star bursts of various types that occur constantly even in our own galaxy. First there are the ordinary novae, of which a few dozen flare up every year in the Milky Way. Although from the standpoint of the inhabitants of a planetary system it would make no practical difference whether their sun exploded with nova- or supernova-intensity (in either case everything would be vaporized in a fraction of a second), the phenomena are of totally different orders of magnitude. A nova at most reaches a maximum brightness of a few hundred thousand suns, whereas a supernova is equal to several hundred million suns. Novae occurring in distant regions of our galaxy can be seen only through a good telescope. Even when a nova is close enough to be observed by the naked eye, it appears no brighter than hundreds of other stars, and can be noticed only by a person who is thoroughly familiar with the pattern of constellations.

An ordinary nova shows the same pattern of physical behavior as a supernova, except that the velocity of expulsion of its gas is smaller, and the mass of the ejected gas shell is a very small fraction of the total mass of the star itself. But a supernova must not be regarded as the extreme case of an ordinary nova, for there is a great gap between them. A star explodes with an intensity of several hundred thousand suns or with an intensity of several hundred million suns, there is no middle ground. This suggests that we may have here a qualitative difference in the nature of the explosive process—a difference as great as that between TNT and atomic bombs.

Below the ordinary novae is a peculiar class of stars that explode much less violently—their luminosities increase only by a factor of 100 or less. These so-called U Geminorum stars, named after their most typical member, blow up periodically at intervals ranging from several days to over a year. The intensity of their explosions is roughly proportional to the period between bursts: stars that explode at intervals of 10 to 20 days increase their luminosity by a factor of 15, those with a period between 50 and 70 days, by a factor of 40, and those with a period of about a year, by a factor of 100.

The Russian astronomers Kukarkin and Parenago have suggested that the U Geminorum stars may have a close kinship to ordinary novae. If we extrapolate to novae the U Geminorum formula for the dependence between the period and the intensity of explosion, we find that the ordinary novae may be considered as U Geminorum stars with periods of 10,000 years or more. The period of astronomical observation is not long enough to prove or disprove such periodicity for the novae. It is significant, however, that two cases of novae that repeated themselves have actually been observed. One is RS Ophiuchi, which exploded first in 1898 and again in 1933. Another is U Scorpii, which exploded three times—in 1863, 1906 and 1936. These two stars seem to lie in an intermediate zone. Their explosions are considerably stronger than those of U Geminorum stars but much weaker than those of most ordinary novae. The observed interval between their explosions is in good agreement with the periodicity formula, for both RS Ophiuchi and U Scorpii increased in luminosity by a factor of a few thousand, which would correspond to a period of 30 to 40 years.

Suppose we applied the same formula to the supernovae. We would find that on the basis of the violence of their explosions their periods would be of the order of many millions of years—which is comparable with the total estimated life of the large luminous stars. From this it seems to follow that a supernova is not a repeating phenomenon. In contrast with an ordinary nova or U Geminorum, which can go on exploding periodically because each time it releases only a small fraction of its total energy, a supernova gives everything away in one giant blow-up. This does not necessarily mean that the explosions of U Geminorum, ordinary novae and supernovae are fundamentally different in origin. It is very possible that a star may start its explosive career with a series of small, frequent explosions, which later become rarer and more intense and finally finish up in one giant outburst.

WE come now to the main question: What is the most plausible hypothesis to explain the explosions of supernovae? It is clear first of all that these explosions are not of a chemical nature, for at the tremendous temperatures of stellar material all chemical compounds are completely dissociated, and in any case, even if the exploding stars were made entirely of TNT they could not release anywhere near the amount of energy observed. We know that all normal stars, including our sun, obtain their energy supply from some system of thermonuclear reactions, the most plausible of which is the so-called carbon cycle that transforms hydrogen into helium. Is it possible that the explosion of a star is due to some other nuclear reaction which is switched on suddenly at a certain stage in the star's evolution?

We may say at once that it is unlikely that a disruptive reaction of this kind would develop in the interior of a star while the carbon cycle was still going strong. The reaction between carbon and hydrogen in this cycle runs at a constant rate, and there seems to be some natural "thermoregulator" that maintains the temperature in a star's interior at the exact value necessary for the process. But when a star finally burns up its supply of hydrogen, the body of the star must begin to shrink. This contraction would be expected to make the star hotter. At that point other nuclear reactions that require higher temperatures may possibly come into action.

The trouble is that it is hard to imagine what kind of nuclear reaction could overcome the self-regulating mechanisms of a star. Whenever the central temperature begins to rise above the critical value, so that there is a danger of a thermonuclear reaction running astray and producing an explosion, a stellar body tends to expand rapidly and reduce the temperature below the danger point.

A possible answer to our dilemma may lie in a suggestion made many years ago by the German astronomer Grotrian. According to this rather paradoxical sug-

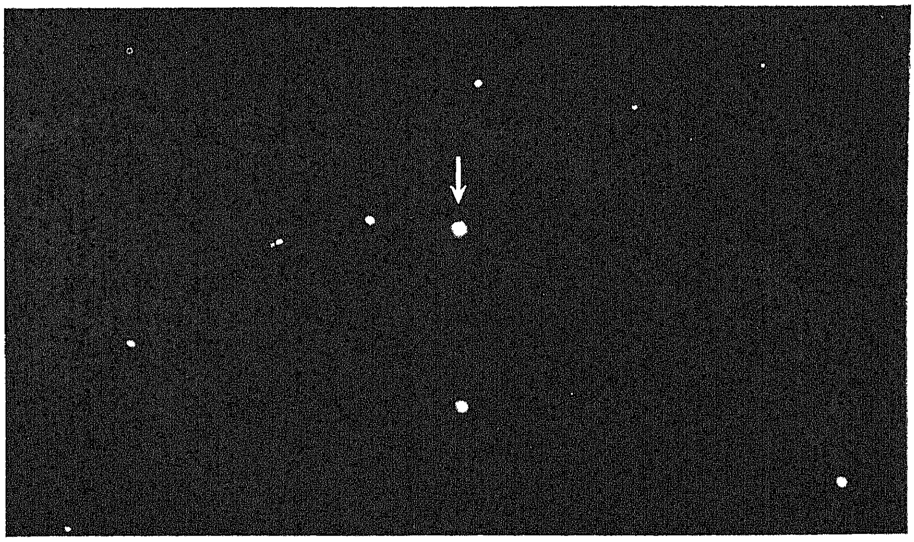
gestion, the explosions of stars are due not to the liberation of energy but rather to the absorption of energy by some nuclear reaction.

To understand this statement, one must remember that the equilibrium of a stellar body rests fundamentally on the exceedingly high central gas pressure that supports the weight of the outer layers. Suppose that at a certain stage of a star's evolution some energy-absorbing reaction were to set in that caused the central pressure to drop suddenly. The body of the star would collapse, much like the roof of a burning building. In the process of such a catastrophic collapse the hot masses from the stellar interior would be forced outward in the form of white-hot streams of matter, and the star would flare up in a sudden flash of light.

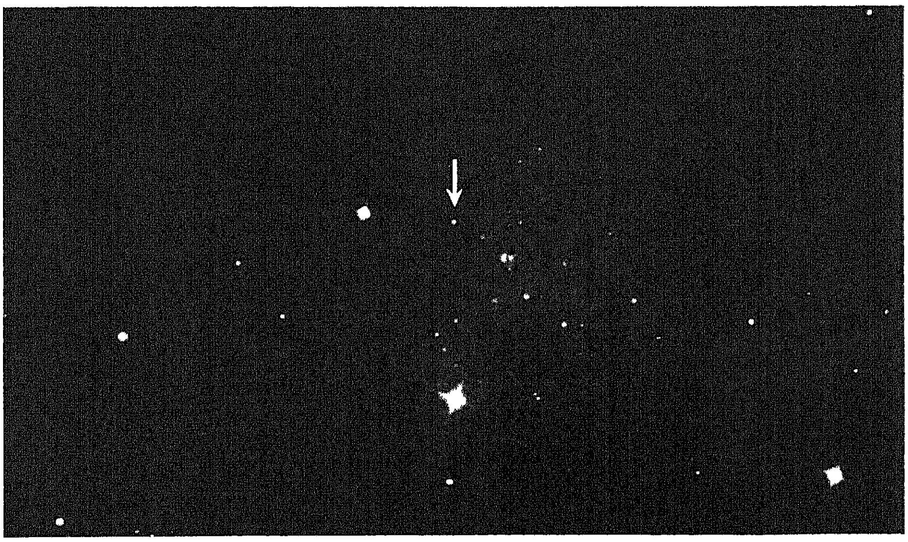
Preliminary studies of such collapse processes indicate that there is indeed enough thermal energy stored in stellar interiors to account for the observed flashes of the supernovae, not to mention lesser explosions. Several years ago the author and his Brazilian colleague Mario Schonberg suggested a certain type of thermonuclear reaction that might lead to the loss of energy in a star's interior necessary to produce such a collapse. The suggestion was that when a star approaches the late stages of its evolution it must develop in its interior a nuclear process producing a large number of neutrinos, the almost massless fundamental particles that have been theoretically predicted but not directly observed, which possess an almost unlimited power of penetration and thus can escape through any kind of enclosure. Once such a neutrino-breeding process set in, heat would escape from the interior of the star, its temperature would drop, and the internal pressure would no longer be able to support the weight of the outer layers. The entire star would collapse and expel white-hot masses of matter in a giant explosion.

The theory of neutrino production in hot stellar interiors can be developed with considerable confidence on the basis of modern findings in nuclear physics, but the treatment of the collapse process itself represents a very complicated problem in hydrodynamics. This problem is too difficult to solve by present methods of mathematical analysis. It seems probable, however, that it can be conquered with the help of electronic computing machines. We hope to set up the problem on a powerful new electronic computer now being built at the Los Alamos Scientific Laboratory of the Atomic Energy Commission.

George Gamow, presently theoretical physicist at Los Alamos Scientific Laboratory, is author of Birth and Death of the Sun *and other books.*



SUPERNOVA WAS PHOTOGRAPHED by an exposure of 20 minutes on September 10, 1937. It is only star visible in extragalactic system IC 4182.



SAME SUPERNOVA HAD FADED so much by November 24, 1938, that a 45-minute exposure revealed it as only one of several visible stars in IC 4182.

SUPERNOVA WAS INVISIBLE by January 19, 1942. An 85-minute exposure did not show it at all. Photographs by Walter Baade of Mount Wilson.

TRANSFORMED CELLS

In the salamander, which is able to regenerate amputated limbs, certain cells return to their unspecialized youth. What is the bearing of this curious phenomenon on such problems as cancer?

by S. Meryl Rose

EVERY living creature starts out on life's journey as a cell or group of cells whose most remarkable feature is a total lack of distinction. Even in man and the other higher animals the embryonic cells from which the complicated organism is destined to develop are, as far as our observation goes, all alike. Only after a certain period of development do the cells acquire special characteristics and functions: some become hair, some brain, some skin, some muscle. The biologist's name for this momentous process is differentiation.

For many years most embryologists have believed that somewhere along the road from the fertilized egg to a fully differentiated cell is a sign which reads, "You cannot return." Up to that point the road permits two-way traffic. While the egg is changing to an embryo its parts can be exchanged without changing the final form of the embryo. Thus when cells destined to be brain are transplanted to a future abdominal skin region, they become transformed into skin cells indistinguishable from cells which had always been on the road to skin formation. Conversely future skin cells, if transferred to the proper neighborhood, will become normal brain cells. In the early stages of development single cells and small groups of cells are extremely plastic, and what they become depends upon the neighborhood in which they grow up.

But there comes a time when the effect of a neighborhood cannot be undone simply by moving to another neighborhood. The cell has been influenced too long; it has passed the critical signpost and can no longer return or cross over to another road. It will continue toward its fated destination even if it is placed in foreign surroundings. Once differentiated, it shows great stability: small groups of cells taken from their normal environment and planted in a suitable nutrient solution can maintain their own peculiar characteristics for many generations.

We know now, however, that this is not the whole story. Evidence is accumulating that the evolution of a cell is by no means as irreversible as used to be thought. Even in the constant environment of a tissue culture, well-differentiated cells of nerve sheath, muscle and connective tissue have sometimes been observed to change mysteriously to an amoeboid form and wander around scavenging on cellular debris. And in a living organism (as well as occasionally in a tissue culture) there is the unhappy fact that normal, differentiated cells can metamorphose into cancerous ones. Unfortunately this is a transformation from one stable type of cell to another; the new cancer cells can reproduce their own kind through many generations.

EXPERIMENTAL proof that under some circumstances cells can turn back, disregarding the one-way sign on the road, has been obtained in certain recent studies of salamanders. The salamander is a convenient animal for the investigation of this problem because it can regenerate amputated tissues. When a limb is cut off a salamander, the stump produces a blastema, or bud, from which a new limb grows. A close study of this process shows that even in full-grown adults the cells that furnish the bud for the new limb first revert to an embryonic type and then can develop into any of a variety of cell types, always in conformity with the neighborhood in which they happen to be growing. In other words, adult cells of the animal dedifferentiate and regain their youth, and then grow up again like young embryonic cells. In the stump of the old limb, where they are influenced by the old tissues, the plastic cells produce only the missing part, no more and no less, and it is perfectly blended with the stump. But if, while still plastic, the blastema is transplanted to another neighborhood, it will develop into an integrated part of its new neighborhood.

What is the evidence that the salamander's adult cells actually do dedifferentiate? Other explanations of the origin of the blastema cells have been suggested. In the early years of this century it was thought that during the regeneration of a limb each old tissue of the limb stump budded and furnished the cells for the new tissues. According to this view regeneration was tissue by tissue, each producing its own kind. For example, new skeletal tissue was thought to arise only from old skeletal tissue. This idea had to be discarded when experiments showed that even if all the skeletal tissue is removed from a stump, new skeleton will still form.

Another theory is that the blastema forms from a reserve of cells in the body which have never differentiated. The great objection to this hypothesis is that there are very few cells in an adult limb which are not differentiated in appearance. And the few that may be undifferentiated do not grow and divide enough to form a blastema. Furthermore, a small segment of a limb can regenerate many times, and it is difficult to see where it could obtain a replenishable supply of reserve cells to make this possible. It cannot get them from a storehouse elsewhere in the body, for experiments have shown that the blastema cells always have a local origin. For example, if a segment from a white limb is grafted to a dark one and then amputated through the white region within a millimeter of the dark tissue, the regenerate will be white. This means that the blastema cells come from the millimeter-thin segment of white tissue at the end of the stump. Not until the cut passes partly through dark tissue and partly through white does the regenerate have any dark tissue in it. Then the part of the new limb adjoining the dark portion of the stump is dark and the part adjoining the white portion is white. There is another test that reinforces this finding. It is known that X-rays can destroy the ability of an animal's tissues to regenerate. If the upper part of a limb is X-rayed and the limb is amputated through the unirradiated lower part so as to leave only a millimeter of unirradiated tissue on the stump, the limb can regenerate. The tiny segment of unirradiated tissue could hardly contain enough reserve cells to create the bud of a new limb, in view of the known fact that very little cell division takes place in the stump before a blastema forms.

So it seems almost certain that the new cells which make up a regenerating bud

must be created by the transformation of old cells. Studies made by means of the X-ray technique indicate that many kinds of tissue can dedifferentiate to supply the limb with regeneration cells. When a salamander limb is X-rayed so it cannot regenerate, the ability to generate a new limb can be restored by grafting to the end of the stump some unirradiated muscle, cartilage or skin tissue All these tissues have in common a certain type of cell, the fibrocyte (which produces fibers) Because fibrocytes are present in most tissues and are relatively undifferentiated in appearance, they have been strongly suspected as the primary contributors to the blastema. Recently, however, we have collected evidence which suggests that the major contributors are not fibrocytes but epidermal cells, which form the outer layer of the skin. Our experiments indicate that these cells can dedifferentiate, that they become a large part of the blastema, and that they can be transformed into such tissues as cartilage and muscle.

EVIDENCE that epidermis is the major source of regeneration cells was first presented 21 years ago by the Polish biologist Emil Godlewski. Godlewski's observation was so out of key with embryological theory at that time that it was discarded as almost certainly an error. A few years ago we began to learn some new facts which caused us to wonder whether the Godlewski story might not be correct. We were attempting to induce limb regeneration in adult frogs. Frogs can regenerate their legs during the tadpole stage but lose this ability when metamorphosis to the adult stage begins. We found that we could make an adult frog regenerate a large part of an amputated limb by irritating the wound with strong salt solutions. Strangely enough, the salt treatments were effective even if they were not given until after the amputation wound had been sealed by epidermis. It was in the epidermis, in fact, that the change began: a large number of epidermal cells migrated over the wound and piled up at the end of the stump on the spot where the new limb bud was about to form.

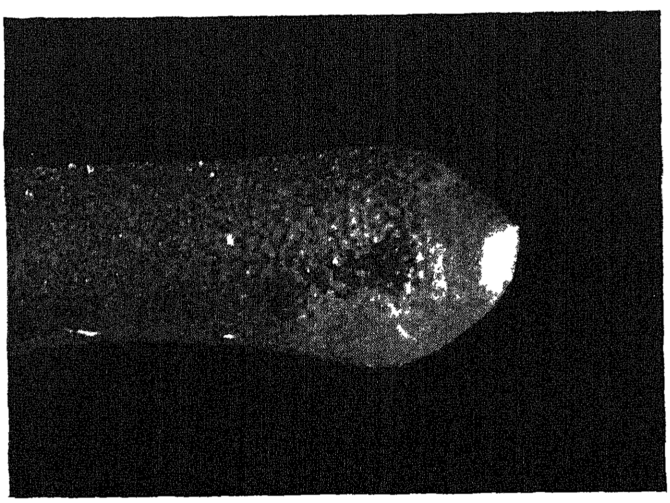
In our next experiment, we replaced skin on the limbs of adult frogs with skin from tadpole tails still young enough to regenerate. We then amputated the limbs, cutting through the young skin and the old internal tissues. The frogs regenerated quite good new limbs. The cells for the new limbs of course came from the transplanted young skin remaining on the stumps. The fact that this skin consisted almost entirely of epidermis and contained very few fibrocytes again led us to suspect the epidermis as a source of regeneration cells.

Following up this clue, we reinvestigated regeneration in salamanders, attempting to trace the plastic cells to their source. Nontoxic dyes were used as a tracer material. We soon discovered that when epidermal cells of regenerating limbs were stained with such a dye, the dye did indeed turn up later in regeneration cells. This in itself was no proof of the conversion of epidermis to regeneration cells, because some of the dye might have been absorbed by phagocytes, or scavenger cells, that engulfed dead epidermal cells, and the phagocytes might have become regeneration cells. However, it was found that the only type of cell that accumulated in the region where the blastema was to form was epidermal cells. When a blastema forms, about 20,000 epidermal cells disappear and simultaneously about 20,000 regeneration cells appear.

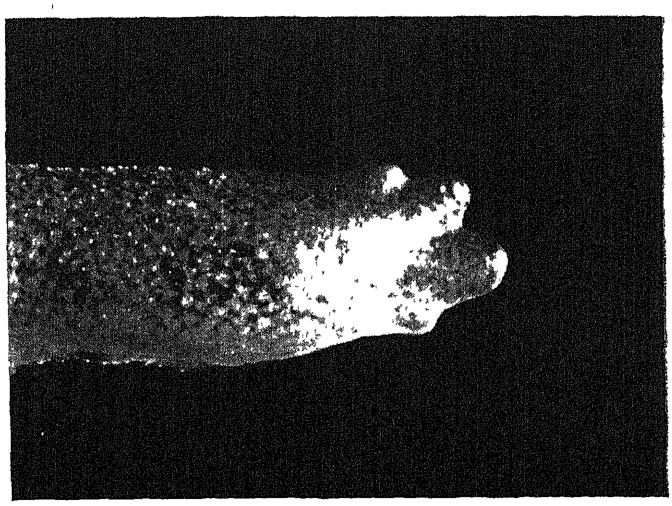
Two further investigations to be completed soon should give us conclusive evidence on the question of whether the epidermis changes into other tissues Epidermal cells with only one set of chromosomes have been transplanted to limbs of hosts with three sets of chromosomes. If regenerates on these limbs contain cells in the internal tissues with one set of chromosomes, it can only mean that epidermal cells have been transformed to cells of quite a different type. In the other experiment unirradiated epidermis has been grafted to X-rayed limbs which are unable to grow or regenerate. If regeneration occurs, the only possible source of the growing cells will be the epidermis.

THE question now arises: what bearing do these findings have on the problem of cancer? The first point to note is that the phenomenon we have been considering, *i.e.*, the reversion of adult cells to embryonic ones, is not quite the same as the transformation of normal to cancer cells. While the latter process also is often spoken of as dedifferentiation, the word then has a different meaning It means that cancer cells lose some of the characteristics of a particular type of differentiation and resemble embryonic cells in their rate of growth. But they differ from embryonic cells in appearance and in the fact that they often retain at least vestiges of their former normal differentiations and do not differentiate when they come under the influence of adult-tissue neighborhoods. It might be better to speak of cancer cells not as dedifferentiated but as abnormally differentiated. Nevertheless it appears that in the case of cancer, as in that of regeneration, we are dealing with a problem in embryology, and that the self-maintaining abnormal differentiation which is cancer might also be lost in a truly dedifferentiating environment. A test of this hypothesis is possible.

The basis of the experiment, which involves transplanting frog tissues to salamanders, is as follows: Frog cells, tissue for tissue, are much smaller than salamander cells. If a certain common cancer of the kidney in frogs could be



AMPUTATED FOREARM of a salamander is tipped with a mound of regenerating tissue. From this blastema develop such specialized tissues as skin, bone, muscle.



NEW FINGERS begin to form after two weeks. If the original blastema is transplanted to another part of the salamander, it exactly reproduces tissue of that region.

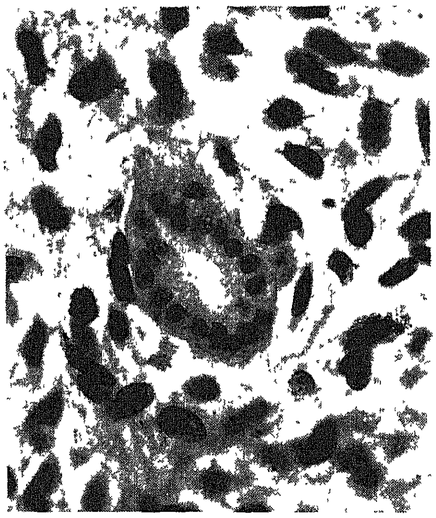
transplanted and grown in salamander limbs, it should be easy to follow the fate of the smaller frog cells in the host. The question was: could frog cancer cells maintain themselves and grow in the foreign salamander environment? Normal frog tissues are almost immediately destroyed in salamanders, but there was hope that the cancer cells would survive. The hope was based on knowledge that some mammalian tumors, especially the malignant ones, not only can survive but flourish in hosts of a different species. Using a new method for maintaining a transplant in a foreign species, we found that we could establish pure cultures of frog cancer cells in salamander limbs.

After the cancers began to grow, the limbs were amputated through the cancer. The salamanders regenerated new limbs as usual, but in some of them patches of frog-sized cells appeared. These differentiated into muscle and cartilage. In other words, the frog cancer cells apparently had dedifferentiated into normal embryonic cells. At first they were well integrated with the surrounding salamander tissues and participated in the formation of normal structures. Before their differentiation was completed, however, they began to be treated as foreign cells and died. This is exactly what would be expected if the frog tumor cells were transformed, for they would develop into frog muscle and cartilage, which the salamander host could not tolerate.

Yet we had to take into account the possibility that the small transformed cells were not actually frog cells but abnormally small salamander cells which had in some way been affected by substances released from the nearby cancer. To decide between these alternatives a sensitive test to identify frog cells was employed. Normal frog tissues were blended, and fluid from the blended mixture was injected into rabbits. The injection caused the rabbits to form specific antibodies to the frog antigens. The rabbit antibodies then served as a test for the presence of frog cells, for when they encounter a solution of frog antigens a cloudy ring forms at the junction of the two liquids. An antibody preparation was applied to a cell culture from the regenerating salamander limbs. A cloudy ring developed, proving that frog antigens were present in the limbs. These frog antigens were certainly not from frog cancer cells, for the cancer had disappeared from the limb some time before. It seems very likely that frog antigens exist only in non-cancerous cells. If so, this test was proof that cancerous cells had transformed to normal.

WHAT is the process that brings about the differentiation of a cell? What aberrations of this process transform one type of cell into another? Some recently learned facts in genetics and biochemistry make it possible to suggest a hypothesis.

The differences that develop among cells when they differentiate are stable differences which can be transmitted to daughter cells through many generations. Yet the genes, the hereditary particles in the nuclei of the cells, apparently do not change during differentiation. The transmission of the cell-changes, that is, cellular heredity, must be controlled by some mechanism other than just the nuclear genes. Tracy M. Sonneborn of Indiana University has recently shown that the single-celled animal Paramecium has a kind of gene, called plasmagene, which lies in the cytoplasm, the part of the cell outside the nucleus. Like the chromosomal genes of the nucleus, plasmagenes help determine the characteristics of the individual Paramecium. In some cases a chromosomal



CANCER CELLS from frog *(small cells in center)* are transplanted in salamander to examine their changes.

gene endows the organism with a certain set of possibilities, but environmental factors, operating through a plasmagene, determine which one of these possibilities will be realized. This kind of system, as Sonneborn has suggested, might form the basis for differentiation. It might work this way, taking a mouse as an example. The fertilized mouse egg has chromosomal genes which say to the cytoplasm, "You may become a mouse liver cell or a mouse kidney cell or whatever mouse cell you wish." But actually the cytoplasm does not have a choice. It is under the control of the cellular environment or neighborhood, which determines what type of cell will form. There is a period during the development of the embryo when great foldings and migrations of sheets of cells take place. It is at this time that neighbors effect great changes in each other. For example, cells migrating forward in the middle layer may induce the cells in the sheet above them to become brain cells. It is unlikely that this process is accomplished by the simple induction of a particular plasmagene in the responding cell, for a cell during differentiation is known to be affected by many neighbors. Instead we have to think of a complex character building up in each cell as the result of multiple inductions. The complex is inheritable and like a plasmagene it probably lies in the cytoplasm. The mechanism of induction may be an antigen-antibody type of reaction.

What kinds of substances could produce these differentiating reactions? The substances seem to exist in a great variety of forms and to reproduce true to type, but they can change on occasion and then reproduce true to the new form. Both these properties are possessed by genes and viruses, which are either pure nucleoproteins or contain large amounts of nucleoprotein. Now the cytoplasm of all cells contains large amounts of ribonucleoprotein. Thus it seems likely that ribonucleoprotein is the differentiating substance.

This conclusion is supported by studies of investigators working with cancer viruses. These are particles which can be obtained from certain cancer cells: for example, a particular kind of cancer in chickens. When the particles are injected into baby chicks, the cells near the site of injection become cancerous, in other words, the injected material transforms the new cell into one just like the cell from which it came. And these cancer-producing particles consist in large part of nucleoprotein.

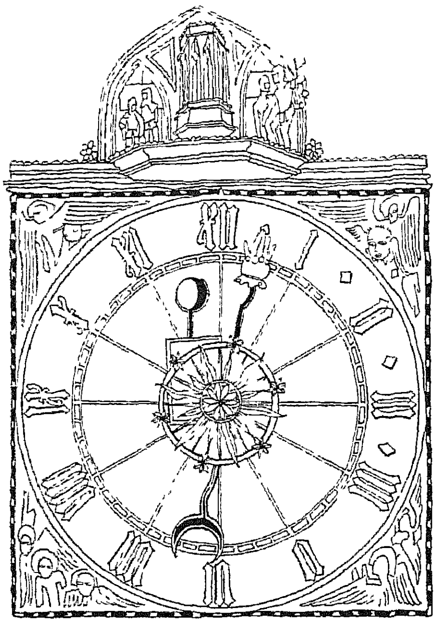
Similar evidence comes from investigations of the various strains of pneumococci, the pneumonia bacterium. Each strain has its own peculiar nucleoproteins. Significantly, when nucleoprotein extracted from one strain is introduced into another, it reproduces true to type in its host and transforms the host into the strain from which it was extracted.

We assume, then, as a working hypothesis, that the differentiation of a cell is the result of the construction of a particular nucleoprotein complex. If this is the case, dedifferentiation would come about through a breakdown or simplification of the nucleoproteins to a plastic form in which they would again be able to react to their neighborhoods and produce new complexes.

Obviously this is a problem of considerable medical interest. If we can learn how the adult cells in salamanders change back to young cells, and can duplicate these conditions in human organs, great opportunities for the repair and replacement of defective parts, and for changing abnormal cells to normal ones, will be open to us.

S. Meryl Rose is associate professor of zoology at the University of Illinois.

SCIENCE AND



The Smoldering Atom

THE Russian atomic explosion faded from the front pages rather quickly, apparently leaving a minimum of residual activity. Despite its seemingly small diplomatic effects so far, however, it set off some new chain reactions which behind-the-scenes observers in Washington, the United Nations and other world capitals have followed with considerable interest.

The opening propaganda move was made by the U.S.S.R. Soon after President Truman's announcement of the Russian explosion, the Soviet representative on the UN Atomic Energy Commission proposed that the U. S. offer "new concrete proposals" for the international control of atomic energy. The five other permanent members of the Commission (the U. S., Great Britain, France, Canada and China) countered by reasserting their support of the "Baruch" plan, insisting that it was essential to any effective system for atomic control. That neither the Commission majority nor the U.S.S.R. was ready to change its position was emphasized in reports made to the UN General Assembly by both sides a month after the Russian explosion. The majority, laying entire responsibility for the deadlock on the U.S.S.R., declared: "The Government of the U.S.S.R. puts its sovereignty first and is unwilling to accept measures which may impinge upon or interfere with its rigid exercise of unimpeded state sovereignty." There was a wide difference between the majority and U.S.S.R. plans for the restriction of atomic energy to peaceful purposes. Stripped of minor issues, the difference was this: international ownership and operation of critical atomic energy activities (the majority plan) *v.* national ownership and operation with periodic inspection by an international agency (the U.S.S.R. plan).

Could any compromise be found between such divergent points of view? The author of the Baruch plan and official spokesmen for the Truman Administration evidently thought not. Frederick Osborn, deputy U. S. representative on the Commission, declared that any agreement on atomic weapons short of "operating and managerial control" would be merely an ineffectual "expression of good intention." Bernard Baruch (speaking for himself) urged the U. S. to accept no substitute for his plan; he held that agreement on a lesser plan would only "create a false sense of security."

It was clear, however, that many U. S. students of the atomic energy control problem did not share these views. One indication of this was the stir created by Chester I. Barnard's article "Arms Race *v.* Control" in the November SCIENTIFIC AMERICAN, in which Mr. Barnard, a coauthor of the Acheson-Lilienthal plan, urged "some changes in our tactics and our attitude." The article was widely discussed in Washington, in the UN and by unofficial commentators. Some critics of U. S. foreign policy went so far as to charge that the U. S. control plan, as presented to the UN, had been deliberately designed to make it unacceptable to the U.S.S.R. In the New York *Daily Compass* the columnist I. F. Stone declared. "I believe the Truman Administration never wanted an agreement on atomic disarmament and does not want one now."

Among U. S. atomic scientists and groups not connected with the Administration there was increasing discussion of compromise plans. Taking the realistic view that agreement on a comprehensive plan for atomic control was impossible at the present stage of cold-war tensions, they proposed that an attempt be made to obtain a limited agreement, such as a five-year convention outlawing atomic arms coupled with some method of international regulation of the mining of uranium and thorium.

Within the UN itself there appeared to be an increasing disposition to discuss compromises, particularly among the smaller nations. Carlos P. Romulo, president of the General Assembly, proposed a truce or moratorium in the production of atomic bombs while negotiations proceed on atomic energy control. A hint of a compromise in the control plans that had been actively discussed was given by Lester B. Pearson of Canada. The proposal was to reduce the scope of international ownership and operation of atomic facilities, in return for which the U.S.S.R. would be asked to agree to permit continuous inspection of atomic plants instead of periodic inspection. Said Mr. Pearson: "If it were possible to give more powers of operation to nations, and take away some powers from the international agency, that would make it all the more important to have complete international powers of inspection at any time without any reservation. . . . Our Russian friends . . . have given no indication whatever at any time that they are willing to accept that kind of international supervision or inspection, and that seems to me to be the fundamental difference between the two positions now."

As this issue of SCIENTIFIC AMERICAN went to press, a public debate of the atomic energy control problem began in the UN. It was obvious that the debate would serve merely as an occasion for polemical attacks on the rival positions. Thus Andrei Y. Vishinsky, Soviet Foreign Minister, delivered an hour and a half speech denouncing the U. S.-sponsored plan. He asserted that the plan "would make it impossible to use atomic energy for peaceful purposes" and that U. S. policy-makers had no intention of agreeing to a prohibition of atomic weapons. As for the U.S.S.R., Vishinsky declared that it was using atomic energy not for stock-piling bombs but for constructive purposes. "We are razing mountains, we are irrigating deserts; we are cutting through the jungle; we are spreading life, happiness, prosperity and welfare in places where the human footstep had not been seen for thousands of years."

Coupled with apparently Soviet-inspired stories in the Soviet-licensed Berlin newspaper *Nacht Express*, which said that the U.S.S.R. had used atomic bombs to blast channels through the Turgai Mountains to divert two Siberian rivers to desert areas, Vishinsky's statement made sensational headlines. Whether or not the U.S.S.R. had enough bombs to "raze mountains," or could use them in this way without creating prohibitive radiation hazards, the statement dramatized the fact that the U.S.S.R. intended to make an emphasis on the constructive uses of atomic energy the keystone of its atomic propaganda strategy.

U. S. Step-Up

IN the U. S. atomic energy program, the Russian explosion had two observable results. One was an acceleration of plans for expansion of plants producing atomic bombs. To enlarge the Oak Ridge and Hanford facilities for production of fissionable materials, the President authorized the Atomic Energy Commission to draw $30 million immediately from budget reserves. When Congress recon-

THE CITIZEN

venes in January he will ask for the appropriation of $300 million more for this purpose.

The other result was an assurance from Great Britain and Canada that the U. S. would continue to get a full supply of uranium from the Belgian Congo and Canadian mines The three countries have been discussing for several months the renewal of an agreement permitting the U. S. to purchase most of the output of these mines (SCIENTIFIC AMERICAN, September). Both the British and Canadians, who had sought a fuller exchange of atomic information with the U S. in return for this renewal, informed the U. S. negotiators after the Russian explosion that the agreement would be renewed without conditions. The Executive Branch of the U. S. Government, including the AEC, favors a more liberal exchange of atomic data, not only with Canada and Great Britain but also with one or two other countries, but has been blocked by opposition within the Congressional Joint Committee on Atomic Energy. When Congress reconvenes the Administration may seek revision of the Atomic Energy Act of 1946 to obtain a clear authorization for the exchange of more atomic information with friendly nations.

Meanwhile the AEC received a clean bill of health in the final report of a majority of the Joint Committee on its investigation of Republican Senator Bourke B. Hickenlooper's charges of "incredible mismanagement." After 45 hearings, the Joint Committee put the charges to a vote. The 10 Democrats voted to clear the Commission; the six Republicans voted against it. The majority, in its 35,000-word report, took occasion to review the entire AEC operation. It credited the AEC with "taking a vast enterprise which was falling apart at the seams and reshaping it into a formidable deterrent against aggression." On the security question, it said. "[There is] no evidence hinting that Russia obtained secrets from the Commission which advanced by one day the date when she completed her first atomic bomb. Likewise, no evidence hints that Russia has acquired information from the Commission which would enable her to improve, by so much as mucilage and tissue paper, the current Soviet bomb designs."

Senator Hickenlooper submitted a brief minority report, supported by his Republican colleagues, which did not repeat the "incredible mismanagement" charge but insisted that "widespread opportunity has been provided for infiltration of subversives" in the AEC and accused the Commission of a "leisurely" approach and "indecision" in development of its program. The majority and minority reports agreed on one thing. research and development in the field of application of nuclear fission to useful power has not been pushed hard enough

Foundation Bill Fails

THE proposed National Science Foundation, which two years ago seemed within sight, appears to become more mirage-like with each passing year The recent session of Congress ended with the Foundation bill quietly and unceremoniously laid away in the House Rules Committee.

In 1947 a bill to create such a foundation passed both houses of Congress but was vetoed by President Truman as unsatisfactory. In the past session a bill calculated to remove his objections was approved by the Senate. It languished for several months in the House Committee on Interstate and Foreign Commerce, and was finally killed by a margin of one vote in the Rules Committee, consisting of four Republicans, three Southern Democrats and five Northern Democrats. The leader of the opposition to the bill in the Committee was James W. Wadsworth, Republican, of New York.

The bill's defeat was due in part to the fact that it was caught in the general political cross-fire that whistled around the Atomic Energy Commission and felled other bills involving new expenditures, notably Federal aid to education and national health insurance The bill was also actively opposed, as before, by the patent lobby. The chief factor defeating it, however, appears to have been a decline in Washington's interest in the measure, President Truman, for example, failed to include it in his list of high-priority legislation. Its opponents argued that the U S is doing well enough in science and needs no national foundation.

Aureomycin v. Radiation

PHYSICIANS who have used the versatile new antibiotic aureomycin sometimes jokingly remark that soon a doctor may need no equipment except a stethoscope and a bottle of aureomycin capsules. The drug has been effective against a remarkable range of bacteria, rickettsiae and viruses. Now a group of workers at the University of Rochester Medical School has found that aureomycin also appears to be useful in the treatment of radiation sickness.

The research, conducted by Joseph W. Howland and associates, was supported by the Atomic Energy Commission. During the past six months they have made

tests on more than 600 rats and dogs exposed to large doses of X-rays. Treatment with aureomycin after such exposure, they learned, alleviates diarrhea and other effects of radiation. The drug has also been tried on human beings. A patient with Hodgkin's disease who after 16 consecutive X-ray treatments became severely ill of radiation sickness showed marked improvement within 48 hours after receiving aureomycin, and was discharged from the hospital within a week. Similar results have been obtained in cancer patients given the drug to control the aftereffects of radium and X-ray treatments.

ACTH

THE new hormone drugs ACTH and cortisone have aroused so much interest in the medical profession that a special conference on them was held recently in Chicago. More than 200 U. S. and Canadian physicians attended it. The center of interest was ACTH, which is at present far more available than cortisone. In terms rare for a physician, Walter Bauer of the Harvard Medical School hailed the discovery of the therapeutic effects of ACTH as "the opening of a new era in medicine."

ACTH and cortisone had already been reported dramatically successful in treating arthritis and a muscular condition called myasthenia gravis, and had shown promise in a few cases of rheumatic fever. Benedict F. Massell and Joseph Warren of the Harvard Medical School, who had followed up the work in rheumatic fever, reported to the conference that 10 out of 11 severely ill patients showed "generally excellent" improvement after ACTH treatment. In two cases the damaged heart valves in patients with rheumatic heart disease apparently healed.

Others at the conference reported that they had had good results with ACTH in asthma, gout, eczema and nephritis. But the physicians were warned that the drug may be harmful and is not to be used indiscriminately. Investigators at Columbia University's College of Physicians and Surgeons said that it can cause severe headaches and raise blood pressure. Furthermore, it has peculiar psychological effects. One woman, after nine daily injections, suffered from mental confusion; another patient became violent and required electro-shock treatments. The warning was given force by the fact that an impure ACTH product has been offered for sale directly to patients, at a cost of $100 for less than a tenth of an ounce. A black market has already sprung up in hog pituitaries, from which ACTH is extracted.

Shortly after the conference a team of investigators at the Memorial Hospital in New York announced that ACTH and cortisone are being used experimentally in cancer. The drugs seem to have some effect on tumors deriving from the lymph tissues, such as lymphosarcoma and Hodgkin's disease. In a test on six patients, three to six daily injections of one of the drugs markedly reduced the size of malignant growths in the lymph nodes and spleen. But the investigators emphasized that "in none of these patients has a complete clinical remission of the disease been obtained." Moreover, when tried against cancer of the breast and the prostate gland the drugs had no effect.

Case of the Trembling Detective

THE chief fingerprint expert of the Lancashire Constabulary in England recently turned up in the London Hospital with a peculiar, unexplained disease. His teeth were coming loose. His hands trembled so violently that he could not lift a glass of water to his mouth without spilling it. His personality had changed radically. Formerly a confident witness at criminal trials, the 45-year-old sergeant now shook and blushed under the mildest questioning.

Two hospital specialists undertook an investigation of the strange case of the trembling policeman. They learned that like most British policemen their patient was in the habit of using a substance called "gray powder," containing 33 per cent mercury, in dusting objects to bring out faint fingerprints. They also recalled that his chief symptoms—tremor, loose teeth and psychological disturbances—were the same as those in a well-known disease known as "hatter's shakes," found occasionally among workers in the felt-hat industry who are exposed to the mercury used in the felting process. Putting two and two together, they concluded that the patient was suffering from mercury poisoning—inhaled gray powder *had affected his nervous system.* This solution was confirmed when the policeman improved after he was instructed to stop using the powder.

The hospital investigators soon found that six colleagues of the fingerprint expert in the Lancashire Constabulary, out of a total staff of 32 men, had the same trouble. *The Lancet,* Britain's leading medical journal, promptly urged that British detectives stop using gray powder. Similar warnings may be expected to follow in the U. S. Detectives of the Federal Bureau of Investigation and many local police forces use the same mercury-containing powder.

Debris Dissolvers

THE draining of pus and other biological debris from the internal tissues of infected patients is one of the most troublesome problems in medical practice. Such accumulations of dead cells and coagulated blood are characteristic of chronic ulcers, tubercular meningitis, severe burns and many other disorders, and often it takes a major op-

eration to get at the regions that have to be drained. Now the problem may be greatly simplified by the discovery of two powerful substances that can liquefy this material and enable the body to discharge it in the urine and other wastes.

These substances are enzymes, extracted, strangely enough, from a most dangerous bacterium, the hemolytic streptococcus. One enzyme is streptokinase (SK), discovered by William S. Tillett of New York University, and the other is streptodornase (SD), identified by Tillett and Sol Sherry. Together with L. R. Christensen, who developed ways of concentrating and purifying the enzymes, they made clinical studies of the substances. They found that injections consisting of five parts of SK to one part of SD dissolved pus and other debris without harming healthy tissues. However, SK retards the formation of blood clots, so the treatment is ruled out where there is risk of severe bleeding.

Phi Beta Kappa Waves

AT Tufts College's Institute for Applied Experimental Psychology, laboratory workers for some years have been using a device for recording a reader's eye movements by registering the electrical currents that accompany the contraction of eye muscles. Recently some of the investigators decided to try to design an electronic machine that would count the eye movements and automatically give the count to the reader. This involved attaching electrodes to the reader's temples and wiring the electrodes to an electroencephalograph, which records and amplifies electrical currents in the head. The psychologists found that the scheme did not work; an unexpected electrical signal from the brain interfered with the eye-movement records.

The brain waves they detected in this accidental manner turned out to be an important discovery. They were not the well-known and much-studied alpha waves of the brain, for they behaved differently. Alpha waves become stronger when the eyes are closed; the new waves did not. The investigators called them kappa waves and began to study them more closely. They found that kappa waves come from anterior parts of the brain, the site of many of the higher mental processes. When a person is not thinking of anything in particular, the kappa rhythm dies down. But a task calling for brainwork, such as multiplying two numbers or reciting the names of the states, makes the waves register much more strongly.

One subject was directed to trace his way through a maze drawn on a piece of paper. While his mind was working hard on the puzzle, his kappa rhythm was strong. After he solved it, at the 25th trial, the kappa rhythm dropped to a minimum. After a 10-minute intermission, the test was repeated. This time the waves hit a low after only six trials, indicating that less mental effort was needed. The investigators concluded that "the kappa rhythm may turn out to be a useful measure of mental work, particularly where the nature of the task is such as to require recall of imperfectly learned material."

How Old Are You?

A MAN is as old as his arteries, so goes the sawbone's old saw. Actually hardening of the arteries is too special a condition to be useful as a measure of the human machine's state of wear or physical age What seems to be a much better index has just been discovered by John H. Lawrence of the University of California He finds that a man is as old as his ability to expel nitrogen gas from the blood. Like many other recent advances in biology, this fact was discovered by means of radioactive tracers.

The average adult at sea level has about 1,000 cubic centimeters of gaseous nitrogen dissolved in his body fluids. The total stays constant, but there is a steady turnover of nitrogen molecules, the body fluids constantly eliminate the molecules they have and take in new ones during breathing. Lawrence had a group of subjects of all ages inhale small amounts of radioactive nitrogen as tracer material. Then he determined how fast they eliminated nitrogen by collecting the eliminated gases and counting the tagged atoms with a Geiger counter. He found that the older a person is, the slower his nitrogen turnover. it took youngsters of 15 only a few minutes to eliminate half the gas, while persons 65 or older took as long as five hours. That the rate of elimination is a measure of physical fitness was shown by the fact that patients in poor physical condition had abnormally slow turnover rates.

Hereditary Schizophrenia?

A STRANGE story which indicates the important role of heredity in mental disease has been reported in *The Journal of Heredity* by E. J. Gardner and F. E. Stephens of the Laboratory of Human Genetics at the University of Utah.

One day a 22-year-old farmer working on his father's land refused to eat his lunch. He shouted that the food was poisoned and his mother was plotting to kill him. He ran off through the fields. When he was found at the end of the day, green stains around his mouth showed he had been eating grass. During the next two months he became worse, and was finally committed to a hospital with a diagnosis of schizophrenia.

Not long afterward, the institution admitted another patient suffering from the same mental disorder. The patient was the grass-eater's identical twin. For five years the twin had been working on his aunt's farm in another state In the same month in which his brother broke down, the twin also ran away from home, screaming that his aunt wanted to poison him.

Birth of the Solar System

TO the numerous recent hypotheses on how the solar system originated, a new one has been added by the astronomer Gerard P. Kuiper of the University of Chicago. His theory. Three billion years ago the sun condensed from a vast rotating cloud of interstellar dust. The remainder of the cloud spun faster and faster around the sun, gradually shrinking and flattening out into a relatively dense ring of solid particles. Then the ring broke into a number of eddies which continued shrinking until the particles composing them fused together into planets.

Kuiper's hypothesis is an attempt to find a plausible synthesis of the recent findings and speculations in this controversial field. It assumes, as Immanuel Kant did, that the solar system was once a rotating cloud. But Kuiper rejects Kant's notion that the planets evolved from hot gases. He suggests instead that they represent the accumulation and fusion of "cold" particles. His idea that the planets formed from eddies in a gaseous ring is like that of the German physicist Carl von Weizsäcker, now a visiting professor at the University of Chicago, but whereas von Weizsacker believes that they formed as "roller bearings" between great vortices in the dust cloud, Kuiper attributes them to gravitational forces.

Kuiper also seeks to account for the chemical composition of the planets by considering the properties of the original ring that girdled the sun. The inner part of the ring, being close to the sun, was fairly hot. Since only dense materials, such as rock-forming silicates and metals, can condense at high temperatures, Mercury, Venus and the Earth, the planets nearest the sun, are composed largely of those substances. The more distant planets—Jupiter, Saturn, Uranus, Neptune—evolved from cooler portions of the ring and contain large proportions of gases, water or ice, hydrocarbons and other lightweight compounds that condense at relatively low temperatures.

According to Kuiper, all this happened within a few thousand years. In the eddies from which each planet was created some material was left over. Around each planet this material formed disk-shaped rings, smaller versions of the great ring that originally circled the sun. And from these rings came the planets' satellites, with two exceptions: 1) the Moon, which did not condense from a ring but was probably formed "ready made" as a double planet with the Earth, and 2) the rings of Saturn, which, due to special conditions that prevented the formation of eddies in them, remain as a

reminder of the process that formed the planets and their satellites.

Comet Caught

WHERE do meteors come from? There is considerable evidence that many of them, at least, come from comets. As a comet sweeps toward the sun, metallic fragments may blow away from its nucleus to form great meteor showers. During one such shower in October, 1946, H. E. Landsberg, a geophysicist of Washington, D. C., coated a sheet of glass with glycerin and on it captured six wedge-shaped iron particles that had drifted down from the sky. These particles are now believed to be the first samples of comet material ever recovered. Fred L. Whipple of the Harvard College Observatory has completed mathematical studies which show that particles of roughly the same shape and cross section (.000016 to .000072 inch) could have passed through the earth's atmosphere without burning away.

Whipple suggests a systematic search for more such "micrometeorites" in ocean sediments, polar snows and geological strata. He believes that a comet is created when the sun passes through an interstellar dust cloud and pulls some of the material away with it. If this is correct, micrometeorites from meteor showers may be actual samples of the particles that float in interstellar space.

Missing Particle

MOST of the elementary particles in the atom seem to come in pairs. The negatively-charged electron has a "mate" in the positron, a positively-charged particle of equal mass. The light and heavy mesons also come in positive and negative forms. But one very important charged particle so far has stood alone, a disturbing exception to the rule of symmetry. This is the proton, the positively-charged nuclear particle. Does a negatron exist, somehow defying detection? Although it seems plausible, physicists have hitherto not been able even to suggest how it might be found.

At a recent meeting of the National Academy of Sciences, however, three physicists came up with an idea. Robert Marshak, J. Ashkin and T. Auerbach of the University of Rochester reasoned that a high-speed negatron would collide with a proton, produce two charged mesons and be annihilated in the process. If this event could be caught on a special photographic plate, it would produce a Y-shaped figure. The stem would be the path of the incoming negatron; the two arms would be the mesons flying off to form an angle of more than 90 degrees. Since only powerful cosmic rays at high altitudes could produce such an atomic explosion, the physicists suggest that negatrons might be observed by sending balloons more than 18 miles into the stratosphere. This experiment should help decide "whether nature is indeed as symmetric as present-day theory leads one to believe."

Currents in the Earth

HAROLD C. UREY, who won the 1934 Nobel prize for chemistry and since the end of World War II has turned geologist, has come out with a new theory about the evolution of the earth's crust. He joins an increasing number of geologists in challenging the idea that the earth was once a ball of molten matter and has been cooling off ever since. On the contrary, he believes that the earth began cool and is getting hotter.

Urey suggests that in the beginning the crust was a "cold" mixture of iron and rock, and stayed that way for about a billion years. Gradually radioactive uranium, thorium and potassium in the crust gave off enough heat to melt the iron. The metal flowed into the interior to form the earth's core, while lighter material "floated" to the surface, forming the present crust.

The rising of cold rock and the sinking of molten iron produced "convection" currents extending vertically from near the surface to the depths of the earth's outer mantle. This circulation caused the crust to wrinkle into great mountain ranges. According to Urey, these currents are still causing land masses to shift and slowing the earth's spin on its axis. As a result, the days are getting longer by about one second in every 200,000 years.

Translating Machines?

IF machines can be built to count, calculate, play chess, even "think," why not a machine to translate one language into another? Scientists have been pondering this possibility.

Two ideas for electronic translating machines have recently been suggested, one by Warren Weaver of the Rockefeller Foundation, the other by A. D. Booth of Birkbeck College in London and R. H. Richens of the Commonwealth Bureau of Plant Breeding and Genetics at Cambridge.

Weaver's idea is based on the discovery by cryptographers during the war that certain frequencies of letter combinations, average intervals between letters and other alphabetical patterns "are to some significant degree independent of the language used." The techniques used to decipher messages in English also worked with surprising success on messages in other languages even when the cryptographer did not know the language of the message. Thus Weaver reports the case of an expert who decoded a column of five-digit numbers and obtained a series of 100 words which apparently made no sense. Linguists found, however, that he had reconstructed the message almost perfectly—the only reason he had failed to understand it was that the words were not English but Turkish!

Weaver therefore suggests that a translating machine might be designed along the lines of wartime deciphering devices. It would treat a foreign language as if it were a special code for English, and would translate the language by deciphering it in English terms.

The British workers—Booth is a designer of calculating machines, Richens a linguist—are planning a translator based on the storage or "memory" apparatus in a mathematical machine. The instrument's memory unit would store foreign words and their English equivalents. After "reading" the material to be translated by means of a photoelectric scanning device, the machine would look up the words in its built-in dictionary, and pass the translations on to electric typewriters. If the machine came across a strange word not stored in its dictionary, it would chop up the word until it found recognizable segments or syllables and give the meaning of those; from these fragments the meaning of the whole word might be deduced.

While translating machines might not be able to do justice to the linguistic niceties of literary or diplomatic English, Richens is convinced they could translate scientific articles. "The resultant translation would be highly artificial and would be what I would call standardized pidgin English. This, though no doubt highly repugnant to those whose main interest . . . is esthetic, will constitute no obstacle to those whose chief purpose in using such a machine is to find out what the original is about."

Refined Pi

IN the middle of the 19th century a dogged English mathematician named W. Shanks computed the value of *pi*, the ratio of the circumference of a circle to its diameter, to 707 decimal places. The job took him more than 15 years. Later mathematicians were content to let Shanks hold the record. Recently, however, some mathematical machine operators yielded to an irresistible temptation and presented the problem to Eniac, the all-electronic calculator at the Army's Ballistic Research Laboratories in Aberdeen, Md. The machine's 18,800 tubes went into action and computed *pi* to 2,040 places. Time: less than 24 hours.

Permanently Creaseproof

TEXTILE chemists have been working for some time on the problem of making fabrics creaseproof. During the war they developed a method of treatment with plasticslike resins that made rayon as wrinkleproof as wool. But the treatment is not permanent; the sub-

stances are simply deposited on the surface of the rayon fibers, and wash off after repeated launderings.

A new process has now been worked out which is really permanent. Developed by D. D. Gagliardi and I. J. Gruntfest of the Rohm & Haas Company in Philadelphia, it changes the basic chemical structure of rayon by building certain formaldehyde-containing compounds into its molecules. The process increases the elasticity of the fibers so that they spring back into place after being twisted or bent. It does not affect the appearance or strength of the fabric. Gagliardi and Gruntfest hope to perfect a similar process for making cotton wrinkleproof.

By comparable chemical alterations Hugh C. Gulledge and George R. Seidel of E. I. du Pont de Nemours & Company have been able to make cotton and rayon fire-resistant. Their process introduces antimony and titanium atoms into the fiber molecules. Ralph G. H. Siu of the Army Quartermaster Laboratories in Philadelphia has also reported a method of chemical reconstruction that protects tenting material and other canvas fabrics against mildew.

Hypersonic Wind Tunnel

THE fastest air flow ever reached in a wind tunnel was reported last month at the California Institute of Technology. The flow in a new tunnel just constructed there attained a speed of more than 7,600 miles an hour—10 times the sea-level velocity of sound. The previous record, 5,300 miles an hour, was set about six months ago in a supersonic tunnel at Langley Field, Va.

The "hypersonic" wind tunnel at Caltech is a joint project of the Institute and the Army Ordnance Department. The apparatus is housed in a special building, but the test section itself is only 25 square inches in cross section and four feet long. Air at high pressures enters through a paper-thin slit, drops to a temperature of about 430 degrees below zero Fahrenheit, and expands suddenly to pick up tremendous speeds on its brief trip through the chamber. It flows past a rocket model the size of a cigarette for testing of the rocket's aerodynamic properties.

The tunnel is to be used in the development of improved rockets and guided missiles. According to published statements, the top speed attained by a rocket so far is 5,200 miles an hour, achieved by a Wac Corporal missile released from the nose of a German V-2 last February. But higher speeds are in the offing, if they have not already been attained. There is a shortage of laboratories to test new models. Of the nation's estimated 125 wind tunnels, only about 30 are supersonic. Before Congress adjourned, it voted more than $252 million for new tunnels. Most of them will be in the faster-than-sound class.

THE FUEL PROBLEM

The demand for liquid and gaseous fuels must sooner or later outstrip our resources of petroleum and natural gas. What of the processes that get these fuels from such solids as coal?

by Eugene Ayres

THE British novelist and critic E. M. Forster has recently been deploring the "implacable offensive of Science." He believes that "we cannot reach social and political stability for the reason that we continue to make scientific discoveries and to apply them, and thus to destroy the arrangements which were based on more elementary discoveries." He concludes that our chances for happiness in the future would be improved if we lapsed into a period of "apathy, uninventiveness, and inertia."

Forster is not alone in this view, of course. But those of us who are directly concerned with the "implacable offensive of Science" are under no such illusion. We are all too aware of the disaster awaiting civilization if a moratorium were to be called upon the advance of science. Indeed, we are by no means sure that science and technology can move forward rapidly enough to prevent the disaster.

The human race has multiplied and reached its present thriving condition at the expense of a fantastically high rate of consumption of irreplaceable natural resources such as minerals and fuels, and of depletion of renewable resources such as fertile lands and fresh waters. The only difference of opinion as to the threatened consequences is concerned with the timetable. In the case of fossil fuels, the optimists believe that the U. S. has enough coal, petroleum, natural gas and oil-shale to last about four centuries. The pessimists put the period of abundance at one century, and even this is based on the proviso that we are able to extract these fuels as fast as needed up to the end. Of course we know that as reserves are depleted a high rate of production cannot be maintained. While production goes down, demand will go up, which will mean a long period of increasing scarcity—unless science finds new sources of energy.

To appreciate the importance of the fuel problem one must try to imagine a world in which the manufacture of steel, clothing, drugs, books, food products, everything, gradually closes down; in which we can no longer heat our homes, or, in fact, build any homes except of logs or mud; in which we are reduced to the tools and weapons of the prehistoric cave man; in which there is no transportation except by domesticated animals, no communication network, and a food supply sufficient to take care of only a small fraction of the people who now inhabit the earth. This denouement is possible only if we stop using our technical wits, but it is inevitable unless we apply knowledge which we do not now possess. If the offensive of science remains implacable, there is every reason to expect that it will develop new sources of energy sufficient to supply even the augmented future needs of mankind.

The problems that must be solved during the next few decades extend into all branches of science. Some of the more distant problems are concerned with the conversion of solar energy into useful heat and power, with the storage of energy, with the maintenance of fertility and with the distribution of fresh water. One of the more immediate problems is concerned with the conversion of solid fuels to liquids and gases, and it is this small phase of the over-all problem that we shall examine here.

Future of Petroleum

The synthesis of liquid and gaseous fuels is important because (1) the world, particularly the U. S., is committing itself irrevocably to a liquid and gaseous fuel economy, and (2) production of petroleum and natural gas is sure, sooner or later, to decline. We expect to need more and more but we shall finally obtain less and less. The consensus of experts in the petroleum industry, as summarized by a Congressional committee in 1947, is that petroleum production in the U. S. will reach its peak between 1955 and 1960, and that by 1967 production will be no more than a billion barrels a year—about half of our present rate of consumption.

Petroleum geologists find that while total additions to proved reserves continue to come along in gratifying volume each year, these additions are made up to an increasing degree of extensions and re-estimates of old fields. The number of new fields found each year remains about the same, but the fields are smaller. We find more million-barrel fields, fewer 10-million-barrel fields and almost no 100-million-barrel fields. The indications are that we may already be on the descending part of the curve of discovery. It is conceivable that unexpected discoveries of very large new oil fields may occur. But to be realistic let us consider the largest oil field ever found in this country—East Texas. The cumulative production of this field over the 18 years of its

life so far has been 2.5 billion barrels. This is only a little more than a single year's consumption in the U. S. at present, and less than the expected consumption in the year 1955. Another "East Texas" could postpone our peak of production only a few months.

The peak of production may be postponed by various other factors. A long-extended economic depression might reduce our demand for petroleum. Political pressure may be brought to bear to increase the ratio of production to proved reserves, thus putting the peak a little farther away. (We would pay for this reprieve by a swifter descent of production later, and by a somewhat lower total recovery of oil from the fields.) We may supplement domestic production by importing oil from foreign fields. This would be logical and effective, for the peak of world production should come several, perhaps many, decades after the peak of U. S. production. Yet allowing for all possible postponements, the day of petroleum shortages cannot be very far away.

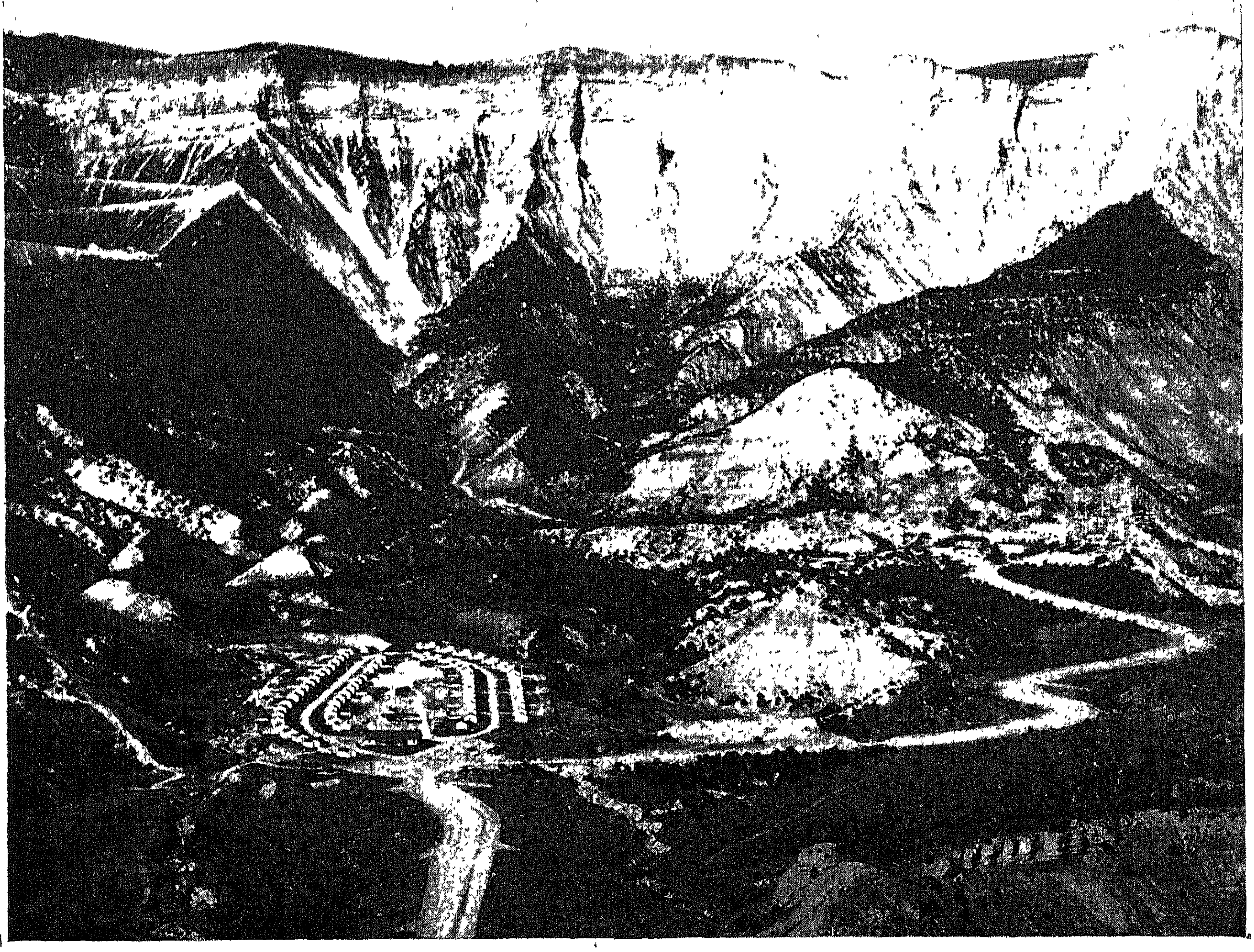
Predictions for natural gas are somewhat more difficult and uncertain. Some gas is produced in association with petroleum; some is not. Geologists believe that an increasing proportion of our gas discoveries will be tied to petroleum discoveries, and this would seem to indicate that the two fuels are in pretty much the same category. The probability is that the peak of gas production will be later than that of petroleum (because we are not using gas at as high a proportion of its reserve), but that the descent of the gas production curve will be even more rapid.

The factor of greatest importance in speeding the day of shortage of liquid and gaseous fuels is, of course, the way in which we are becoming increasingly insistent upon devices that require such fuels. We must have our motor cars, our airplanes, our agricultural machinery, our Diesel-electric locomotives, our oil-burning and gas-burning domestic furnaces. We are rapidly giving up coal as a fuel for many purposes: the manufacture of coal-steam locomotives has come to a virtual halt and many old locomotives are being junked; almost no coal-burning ships are being built; relatively few coal-burning furnaces are being installed in new homes; even stationary power plants, because of a temporary economic attractiveness of liquid fuel, are converting to oil.

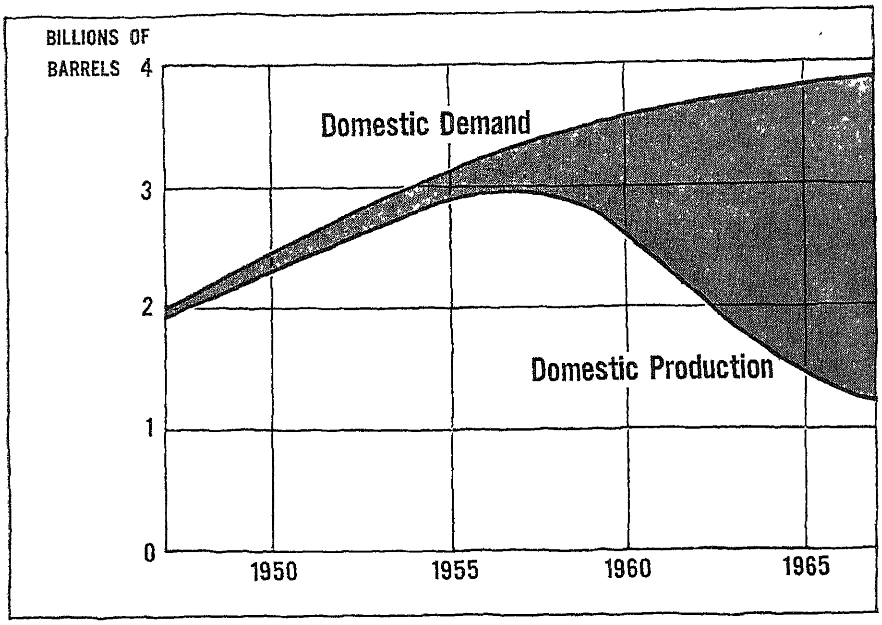
So one of our major problems is to convert our various kinds of solid fuel to liquid and gas. On strictly economic grounds the necessity for doing this is not immediately apparent, because for some time to come it will be more profitable to import oil from foreign fields than to convert domestic solids. But there is a natural reluctance to be dependent for the lifeblood of our industries and our military establishment upon the friendliness of other nations. And in any case, as the other nations of the world rise to a higher state of industrialization, international competition for oil will grow keener and the price will rise. All this should stimulate technological research to lower the cost of synthesis of liquid fuel and make it competitive.

The Two Sources

The most abundant of the solid fuels may be divided roughly into two classes: the oil-shales, which are largely inorganic, and the coals, which are largely organic. The oil-shales are rocks that contain some carbonaceous material fair-



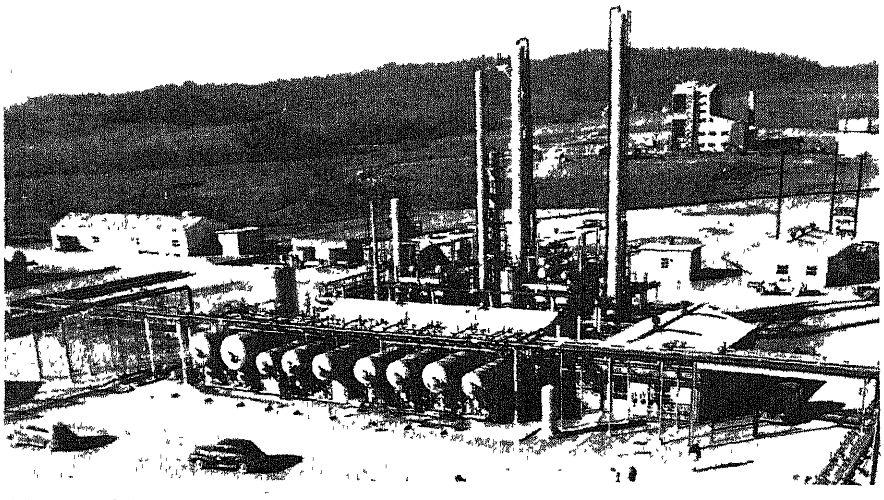
CLIFFS OF OIL-SHALE tower above the Bureau of Mines Oil Shale Demonstration Plant near Rifle, Col. The mine area is barely visible at upper left. A residential area is at lower left. The plant is at right.



SUPPLY AND DEMAND of liquid fuels is predicted, largely on the basis of the testimony of experts before a Congressional committee in 1947. Gap might be filled by importing petroleum or converting solid fuels to liquids.

	CENTS PER GALLON
WYOMING CRUDE PETROLEUM	12.2
NATURAL GAS BY FISCHER-TROPSCH	15.0
OIL-SHALE	22.5
INDIANA BITUMINOUS COAL BY FISCHER-TROPSCH	22.5
MONTANA SUBBITUMINOUS COAL BY FISCHER-TROPSCH	27.6

RELATIVE COST of gasoline synthesized from various raw materials has been estimated by experts of Stanolind Oil and Gas Company. Cost of converting coal will probably be reduced more than that of converting oil-shale.



HYDROGENATION OF COAL is conducted in a demonstration plant built by the Bureau of Mines near the town of Louisiana, Mo. The pipes and vessels shown in this picture make up the distillation area of the plant.

ly rich in hydrogen, and they therefore yield some gas, liquid and coke when heated. The coke cannot be recovered, because it is associated with the predominant rock, but it can be burned to provide the heat for "retorting" processes that recover oil and gas from the rock The earth has an abundance of shale capable of yielding 30 or more gallons of oil per ton

The coals are carbonaceous bodies of varying hydrogen content and with variable but minor amounts of inorganic material. The coals, like oil-shales, yield gas, liquid and coke when heated, but in this case the coke is a major recoverable product, there is much more coke than is needed as fuel to supply heat for the conversion Anthracite, which contains very little hydrogen, yields little gas or liquid. The bituminous coal now used for coke-making yields on the average about 10 gallons of liquid per ton. This liquid yield can be raised to 30 gallons per ton by retorting at a lower temperature, but the coke made in this way, while an eminently satisfactory fuel, is not suitable for blast-furnace use. Some rare coals, containing more hydrogen, will give up to 100 gallons of oil per ton, and so will some rare oil-shales.

The liquid and gaseous fuel industries actually started not with the discovery of petroleum and natural gas but with the conversion of coal and oil-shale. The coking of coal is a very old art. Coke was used for house-heating as early as the year 1587, when Mary Queen of Scots was beheaded by Queen Elizabeth. The first patent on a process for coking coal (British Patent 15) was issued in the year 1620, when the Pilgrims made their historic voyage on the *Mayflower* Coke was first used for blast-furnace operation, replacing charcoal, in 1709. The gas, tar and chemicals boiled off in coke-making were at first disregarded, but in the year 1760, when James Watt was beginning his experiments with the steam engine, an attempt was made to commercialize the recovery and use of the gas and tar. By 1792 tar was in profitable commercial production. By 1812, the year of Napoleon's retreat from Moscow, more than 120 miles of coal-gas pipeline had been laid in London.

Meanwhile it had been found that liquid fuel could be recovered from oil-shale. In 1815 (Waterloo) commercial oil-shale retorting was started in New Brunswick, Canada, and between 1850 and 1860 more than 50 commercial plants were in operation on the eastern seaboard of the U. S to distill oil from shale imported from Canada and from cannel coal imported from Scotland. These plants formed the nuclei of the petroleum refineries that were to come along later Cannel coal (so called because it was found to burn like a candle) is a solid fuel intermediate between oil-

shale and coal Discovered in Scotland in limited quantities before 1850, it came into great demand as a source of kerosene or "coal oil." The Scottish supply of cannel coal was soon exhausted, and Scottish plants turned to oil-shale, which was in greater supply. The oil-shale retorting industry has continued on a modest scale in Scotland ever since

The mining of oil-shale in Scotland has always been a laborious and expensive operation. Much of the shale is 300 feet below the surface, and Scottish mining has never become highly mechanized. The retorting of the shale has improved only slowly—at first because the operation was profitable with crude technology, and later because the industry was subsidized by the British Government as a gesture toward nationalistic self-sufficiency. Ordinarily there is little incentive for research and development in a subsidized industry where profits are nominal and fixed by governmental fiat. In the early days, however, James Young became sufficiently wealthy from shale oil manufacture to finance the last African expedition of the Scottish missionary and explorer David Livingstone.

In this country, the oil-shale industry was abandoned as soon as ample supplies of petroleum and natural gas were found. The recovery of liquid and gaseous fuels from coal, however, was continued, because of local markets for gas, coke and chemicals. The first reasonably complete recovery coke-ovens in this country were installed at Syracuse, N. Y., by the Solvay Process Company in 1893. Their primary objective was not the coke, nor the liquid and gaseous fuels, nor the aromatic chemicals, but the ammonia! However, the other materials were appreciated—particularly the gas, then highly prized for lamps.

A Cast of Characters

In 1900 John D. Rockefeller, then 61 years old, was putting the finishing touches to his petroleum empire. His original Standard Oil "trust" had been dissolved just a year before. His empire was a tiny thing by modern standards. All the oil that had been produced in the U. S. up to that time would not have sufficed to operate our present economy for six months. The principal use of liquid fuel was still for kerosene lamps.

A strange assortment of contemporaries of Rockefeller, however, was destined to be instrumental in making him one of the wealthiest men of all time, and in bringing about a more radical change in our way of life than had any other set of people in the history of the human race. Rockefeller might have been mildly interested in some of these men, but he could not have realized at that time the vital character of the new technical ideas that were then already under development, and the magnitude of the forces of consumption that were about to be unleashed.

One of the men he would have been least likely to understand was Josiah Willard Gibbs, professor of mathematical physics at Yale University, who by founding the science of physical chemistry laid the basis for modern chemical engineering and the processes that were to revolutionize fuel chemistry. Another was the German chemist Wilhelm Ostwald, who, building on earlier investigations by Jons J. Berzelius of Sweden, Michael Faraday of England and Ludwig F. Wilhelmy of Germany, was the first to suggest the great importance of chemical catalysts. Then there was the brilliant French chemist Paul Sabatier, who during a classical series of experiments with contact catalysts had produced a catalytic reaction between carbon monoxide and hydrogen to make methane, thereby establishing the starting point for the most important of present projects for the manufacture of synthetic fuel. He was to discover many other hydrogenation reactions that were later to be applied to the solution of the fuel problem. There was Thaddeus S. C. Lowe, an American engineer who, seeking a process to make water-gas to inflate balloons, had succeeded in building the first practical plant in this country for the production of carbureted water-gas from coke. There was Carl von Linde, a German engineer who had built the first practical plant for the liquefaction of air and the preparation of oxygen, which was to become a commercial means for the conversion of the batchwise water-gas process to a continuous process. There was Charles E Robinson, metallurgist, who, attempting to improve the roasting of ores, had taken out a patent on the idea of bringing gases into contact with finely divided solids—an idea that was to become of great importance in fuel catalysis. There was the young Russian chemist Vladimir N. Ipatieff, who had started his pioneering work on catalytic reactions under high pressures and at high temperatures, which was to create the basis for the processes of destructive hydrogenation of oil and coal.

In another part of the forest was a group of contemporaries and near-contemporaries whose work was destined to create huge markets for liquid fuel: Nikolaus A. Otto, the German engineer who had developed what has since been called the "Otto cycle," upon which all conventional gasoline engines are based; Rudolf Diesel, who had just invented the oil-burning engine that bears his name; the German engineer Wilhelm Maybach, who had applied Otto's engine to a vehicle and had added the spray-nozzle carburetor, the honeycomb radiator and the variable speed gear to make perhaps the first "horseless carriage", Samuel P. Langley and the Wright brothers, who succeeded in flying the first power-driven airplanes, Nikola Tesla, who had just invented the alternating-current electric motor, Thomas A. Edison, who had developed a practical incandescent electric lamp, Charles H. Cramp, who was developing the conversion of ships from sail to steam. None of these men, least of all John D. Rockefeller, could have appreciated the consequences of their acts. In 1900 no one could have foreseen the 40 million automotive vehicles on the road today, or the half-million barrels a day of fuel consumed by the airplanes of World War II, to say nothing of the even greater consumption of our planned fleets of jet planes.

The beginnings of the technical knowledge that was to create the liquid-fuel era were all present, but they were only beginnings. Extraordinary progress in research in many different fields was to be made during the next 50 years. The petroleum industry was to grow into an indispensable giant serving us in countless ways through machines of superlative ingenuity. And the processes of liquid-fuel synthesis were to be developed toward the stage where they could prolong the liquid-fuel era far beyond the relatively puny life of petroleum itself. These processes are approaching the stage of economic practicality, and they could be invoked even now in an economic or national emergency.

Converting Oil-Shale

What are the problems that lie before us in converting our resources of solid fuel into liquid fuel? Let us consider oil-shale first. There is an abundance of oil-shale in Colorado, and ample additional supplies in Utah and Wyoming. With the knowledge of this abundance and of the need to make large-scale use of shale oil at some future date, considerable work has been done on various phases of the problem. The major progress so far has been in mining, in which the Bureau of Mines has done a magnificent job. The problem in Colorado is much simpler than in Scotland or in other oil-shale locations because of the great thickness and accessibility of the beds. We now have tremendous machines that facilitate mining, for example, there are power scoops used in the strip-mining of coal that take 45 cubic yards in one scoop, whereas the largest power scoop used for the construction of the Panama Canal had a capacity of only eight cubic yards. Until recently, one man in a mechanized mine could produce about six tons of coal per day; now under certain favorable conditions one man can mine up to 100 tons per day. The Bureau of Mines furthermore has developed a unique mining system specifically applicable to the oil-shale beds.

Several new processes are under development for the retorting of shale. They

involve the grinding of the shale and the continuous passage of the ground material through a chamber with a countercurrent passage of air or hot gas. The improvements over earlier processes come primarily from the use of more modern chemical and mechanical engineering design, and this, in turn, comes largely from the quantitative relationships developed by the academic mathematicians. The refining of crude shale oil to obtain products of competitive quality presents no serious problems that are not encountered in the refining of the less desirable grades of crude petroleum. Except for its higher cost, shale oil is a perfectly satisfactory substitute for crude petroleum

Chief among the general problems still to be solved in the commercial production of shale oil is the aridity of the regions in which oil-shale is found. While the production of crude shale oil requires only a tenth as much water as the coal conversion processes, the problem will still be formidable. In the Western states, where the bulk of our reserves of coal and oil-shale lie, there is a grotesque contrast between the robust grandeur of the land masses and the pathetic trickle of the rivers. Another problem is the disposal of ash. We are accustomed to thinking of ash as a little bit of stuff that is left over In the case of shale we shall have, on the average, well over a ton of ash for every barrel of oil. And this ash is material without fertility. It has been estimated that we may ultimately obtain about 365 billion barrels of shale oil. This would leave enough ash to cover the entire state of Colorado to a depth of 10 feet. Much of it could be dumped in the huge canyons of the oil-shale regions, and it would seem that the first billion tons will not be impossible to manage, but the disposal of 500 billion tons will require extraordinary ingenuity.

When the oil-shale industry develops, it may well find ways to convert some of the wastes into useful chemical by-products containing nitrogen or oxygen or sulfur. The by-products from oil-shale distillation include new chemicals such as the substituted pyrroles. And large-scale production of shale oil could yield as a by-product more ammonia than is consumed in present world markets. We may be thankful some day for such a generous source of supply.

Hydrogenation of Coal

Now what about coal as a source of liquid fuel? In the long run we can expect to obtain much more oil from coal than from shale. In the case of shale the modern problem is to utilize the best possible engineering to get, at lower cost, about the same yield of fuel as in the 19th century. In the case of coal the modern problem is to apply 20th-century chemistry to increase the yield of liquid fuel to several times its normal value. One way to accomplish this is by hydrogenation

The term hydrogenation has come to be used for any reactions that are carried out in the presence of hydrogen. The original organic hydrogenations were those in which hydrogen was added to an unsaturated molecule to make a more saturated one; this is the process used in making paraffins from olefins, or vegetable shortening from vegetable oil. In the latter case the hydrogenation changes a liquid to a solid. The hydrogenation of coal is an entirely different thing. The physical result happens to be the change of a solid to a liquid. Chemically there is a reduction in average molecular weight (instead of a slight increase) and a reduction instead of increase in the degree of hydrogen saturation. An illustrative reaction is the addition of one mole of hydrogen to one mole of diphenyl to make two moles of benzene. Here we do not get the volume decrease characteristic of classical hydrogenations, because the consumption of hydrogen has been accompanied by decomposition. Another difference is in the effect of catalysts. The hydrogenation of coal is speeded up only moderately by catalysts, whereas classical hydrogenations frequently do not occur at all without catalysts.

In 1913 Friedrich Bergius, a German chemical engineer, discovered that certain kinds of coal could be almost completely liquefied by heating the coal to a high temperature under a high pressure of hydrogen. This work was an extension of the earlier work of Ipatieff. Bergius did not at first use a catalyst, and his reaction was batch-wise (noncontinuous) and slow. It is still batch-wise and slow. There is enormous room for improvement in the catalysis of coal hydrogenation. The intense world-wide search since 1913 for catalysts for this purpose has been characterized by a frantic desire for patent protection rather than by a scientific quest for truth. All the metallic elements of the periodic table (except two rare ones), and endless combinations of them, have been patented as catalysts. These patents have now expired. The catalysts described are nearly all worthless; the best of them merely double the rate of reaction. In sharp contrast, a typical catalytic reaction in petroleum chemistry—the use of sulfuric acid to speed up the reaction between butene and isobutane to make an aviation fuel—produces an acceleration of the process equivalent to a change in velocity from one foot per 5,000 years to 186,000 miles per second, the velocity of light.

In the Bergius process for coal hydrogenation, powdered coal is mixed with tar from a previous run to make a thick mush. A little tin chloride or iron oxide is stirred in and the heterogeneous mess is forced into a pressure vessel with hydrogen at several thousand pounds per square inch. Here it is heated for an hour or so, and the resultant stuff is separated into (1) crude products, (2) material for recycle, and (3) wastes, such as ash. U. S engineers have added little of importance to the fundamental conceptions of the German technologists. We have not yet succeeded in speeding up the reaction to the point where the hydrogenation of coal can be made truly continuous.

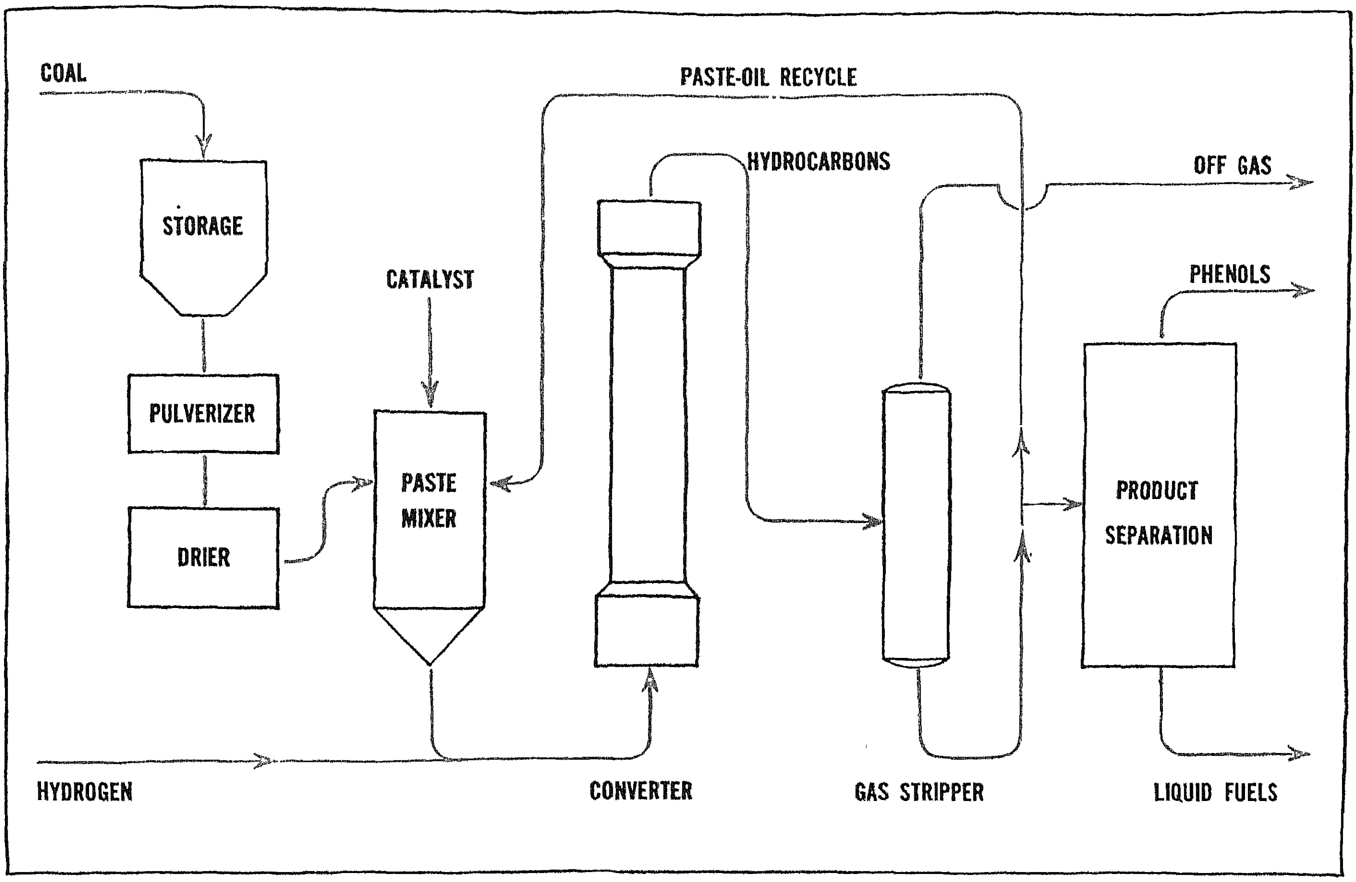
The products of coal hydrogenation are about the same as those from the coking of coal, except that we get little or no coke. Some of the carbon of the coal appears in the liquid and gas, some is used up to supply hydrogen and heat for the process. The latter factor creates an important problem. There are only two sources of industrial hydrogen—hydrocarbons and water. Each may be decomposed to make hydrogen. But hydrocarbons are the things we want to make rather than destroy. This leaves water as the only practical source, and to obtain hydrogen from water requires the "burning up" of carbon. A direct reaction between water and carbon forms hydrogen and carbon dioxide. The latter is readily removed. However, since carbon dioxide is an unwanted, though inevitable, product, the generation of hydrogen through the aid of coal involves what amounts to the destruction of a portion of the coal.

For this reason the Bergius process has so far not been seriously taken up as a method for producing liquid fuels, although some chemical companies have considered the limited use of coal hydrogenation for the production of needed chemicals, with fuel as a secondary product. One such plant has already been announced. Such a plant could produce large amounts of phenol or naphthalene —chemicals now in short supply.

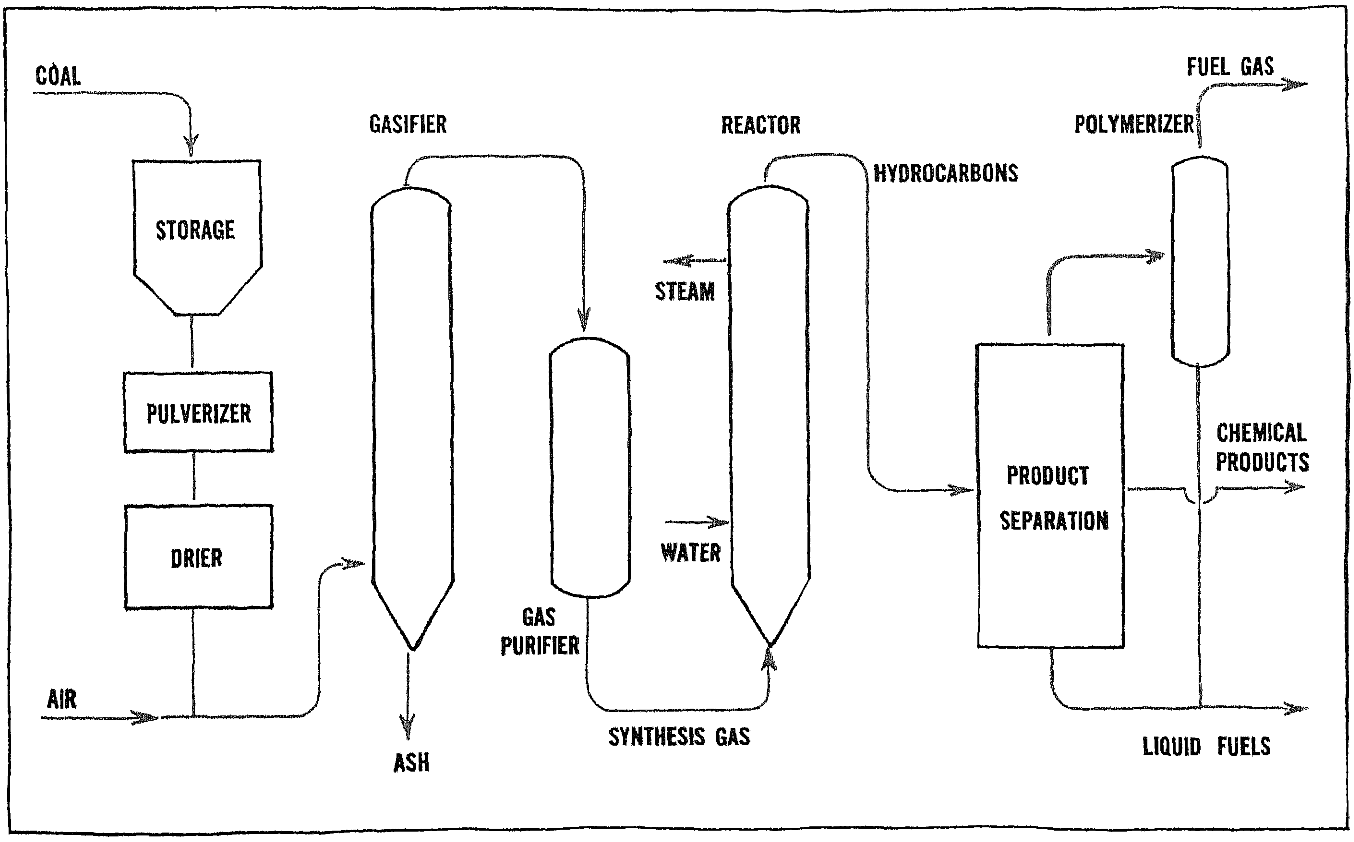
A promising modification of the coal hydrogenation process is to convert only the easier portions of the coal to liquid and gas, the rest of the coal going to coke. The idea may have possibilities, because the reactions are more rapid, require less hydrogen and take place at lower pressures. The process involves less over-all waste of fuel. The yield of liquid is lower than from complete hydrogenation, but additional supplies of liquid can be obtained from the coke by another process.

Fischer-Tropsch

This is the so-called Fischer-Tropsch process, an idea fundamentally different from that of Bergius. After Sabatier had shown that carbon monoxide could be hydrogenated over a nickel catalyst at atmospheric pressure to make methane, other investigators began to try the higher-pressure technique developed by



HYDROGENATION PROCESS is outlined in a simplified flow chart. Powdered coal is mixed with tar from a previous run (*paste mixer*) and then subjected to several thousand pounds of pressure in the presence of a catalyst and hydrogen (*converter*). The principal drawback of the process above is that it is not continuous.



FISCHER-TROPSCH PROCESS begins with air and any carbonaceous material that will burn. In this case the combustible material is coal. The product of its combustion is carbon dioxide, which can be reduced with hydrogen to form carbon monoxide, which in turn can be reduced with hydrogen to form hydrocarbons.

Ipatieff. They discovered that under these conditions the hydrogenated product was not predominantly methane but a mixture of hydrocarbons of various molecular weights, some of them liquid Eventually certain investigators whose names are lost to fame found that the use of higher pressures and suitable catalysts yielded methanol as the predominant product, while more moderate pressures and other catalysts produced various other liquid and solid hydrocarbons. Two German chemists, Hans Fischer and Franz Tropsch, publicized this work in 1922 and for this modest contribution achieved technical immortality.

The raw product of the Fischer-Tropsch process is carbon monoxide and hydrogen. This mixture is known as synthesis gas It is possible to prepare these gases from any carbonaceous material that will burn. This includes wood, charcoal, oil-shale, coal, coke, natural gas and other hydrocarbon gases. When these materials are burned with plenty of oxygen or air, we get carbon dioxide, which can be reduced with hydrogen to carbon monoxide, which in turn can be reduced with more hydrogen to hydrocarbons. Such a procedure is extravagant in its hydrogen requirement. As we have seen, it is desirable to use a sequence of reactions that will require a minimum of hydrogen. This end can be attained in various ways. For example, incomplete combustion of carbon gives carbon monoxide instead of carbon dioxide, thus minimizing the need for hydrogen to reduce carbon dioxide Incomplete combustion of carbon in the presence of steam gives both carbon monoxide and hydrogen. The two gases can be obtained also from the incomplete combustion of hydrocarbons or by the reaction between hydrocarbons and steam. The selection of the plan depends upon economics.

Some of these reactions give more than enough hydrogen for the synthesis while others give too little or none. The ratio of hydrogen to carbon monoxide in the product can be increased by means of a simple catalytic reaction between carbon monoxide and water to give carbon dioxide and hydrogen. This reaction is technically useful but essentially wasteful because it diverts some of the carbon to carbon dioxide.

You will note that many of these reactions involve oxygen. Most continuous processes require reasonably pure oxygen, because when air is used the synthesis gas product is diluted with nitrogen, which impedes satisfactory hydrocarbon formation. There is a definite possibility, however, that a technique can be worked out which will yield nitrogen-free synthesis gas even when air is used instead of oxygen. Some of the more optimistic cost estimates for the manufacture of motor fuel from coal by the Fischer-Tropsch process assume that air combustion can be made practicable.

The Cost Problem

The various reactions mentioned for the preparation of synthesis gas are not new. Synthesis gas is merely the water-gas of the 19th century, adjusted for ratio of components, and prepared according to identical chemical principles Water-gas is now being manufactured for use as a domestic fuel, as a source of hydrogen for synthetic ammonia, and in the synthesis of methanol For these three purposes, water-gas has been cheap enough, but all the water-gas now manufactured in this country would not make more than 16,000 barrels a day of motor fuel—a tiny fraction of our motor fuel consumption. If we are to use water-gas as a basis for liquid motor fuels, we shall have to learn how to make it much more cheaply than it has been made in the past. The trouble with the old water-gas process is that it is not continuous and it works well only when coke is used as the solid fuel. The synthetic liquid-fuel industry cannot afford to start with expensive coke.

The Fischer-Tropsch synthesis itself is fundamentally very simple. You have a catalyst chamber. You put in gas at one end and take out gas from the other end The gas going in is a mixture of one part carbon monoxide with about two parts hydrogen. The gas coming out contains hydrocarbons. The process can be regulated to give only gas or to give an optimum yield of liquid fuel. It may be made to give wax with up to 2,000 carbon atoms per molecule, or to give a variety of oxygen-containing chemicals Even under conditions believed to be optimum for gasoline, some ethyl alcohol is formed. So, in spite of the simplicity of the process idea, it is necessary to control a large number of process variables in order to make the things that are relatively profitable and to avoid making the things we do not want.

Bear in mind that the successful development of this process would not only give us liquid fuels but would also give us cheaper domestic gas, synthetic ammonia and methanol, and a convenient method for making many useful chemicals, such as alcohols, acids, esters and various other organic compounds.

The proportions of the various hydrocarbon products yielded by the Fischer-Tropsch process depend upon the catalyst used and upon a dozen conditions of operation. The catalyst preferred by the Germans was cobalt. The catalyst preferred in the U. S is iron, because iron permits the use of higher temperature ranges without bad effects and is less costly. At higher temperatures the reaction takes place more rapidly, which means that equipment for a given capacity is much smaller, which means that fixed charges on the manufacture come down to a more reasonable point. The higher temperature means that fewer chemicals are formed Even with the iron catalyst, however, the volume of chemicals may ultimately prove to be a strain on market demand. The iron catalyst also has made possible the production of relatively high-octane-number gasoline instead of the abnormally low-octane-number gasoline obtained with cobalt.

Coal *v.* Shale

Real progress has been made in the Fischer-Tropsch process during the past few years. Technologists in this country have reduced the requirement of steel (*i.e*, plant) per barrel of product to one fifth of its previous figure. However, we must not lose sight of the fact that the Fischer-Tropsch process is a net consumer of energy, that is, the liquid fuel it produces yields less energy than is required to produce it. We cannot think of the complete conversion of coal to liquid by any process as conservation of our fuel resources. It is, instead, a wasteful expedient that can be justified only by a compelling necessity to produce more liquid fuel than can be obtained from other sources. This is in sharp contrast with the conversion of oil-shale, which is not usable as a fuel until it is treated to recover its oil. Every barrel of oil recovered from shale would avoid the eventual destruction of a quarter of a ton of coal. Thus shale oil recovery would constitute a most important measure of conservation.

The essence of the problem of future development of the Fischer-Tropsch reaction is the finding of means to balance the power required by the process with the power produced, through the utilization of a minimum of plant and equipment per barrel of product. By the time it is necessary to use the process on a large scale many economies will have been developed and the process will be applied in judicious combination with other processes. An example of such a combination would be the low-temperature coking of coal, the use of the coke as industrial fuel to the extent that markets could absorb it, and the Fischer-Tropsch conversion of the remainder.

This combination would seem to be a much more logical first step than the conversion of oil-shale. It seems most unlikely that we shall turn to the processing of oil-shale to get from each ton 30 gallons of crude oil plus ash as long as 30 gallons of crude oil plus coke can be obtained from a ton of coal more cheaply. The former does not make economic sense. The conservational aspects of shale oil recovery will be just as valid toward the end of the fossil fuel era as toward the beginning.

As for the choice between hydrogenation and Fischer-Tropsch, there is no doubt that coal hydrogenation can be

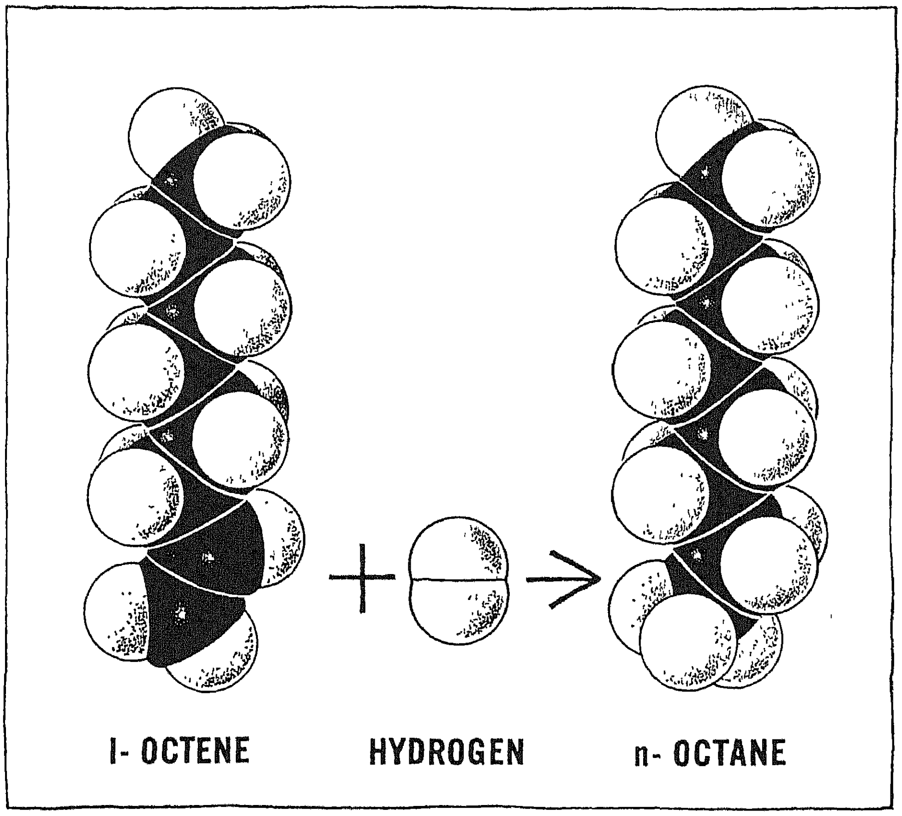
greatly improved by research, but so can the Fischer-Tropsch process. It now seems most probable that hydrogenation will be applied in the future not to coal but to obtain light fuels from heavy oils.

Meanwhile the possibilities of the versatile and flexible Fischer-Tropsch process are being explored in several directions. A Fischer-Tropsch plant is now being erected in Texas to operate on natural gas instead of coal or coke. The list of chemicals expected as by-products in this plant reads like a catalogue of aliphatics. Under present technology it does not appear possible to reduce the by-product ethyl alcohol created by the process to much less than four per cent by volume of the synthetic gasoline. It is estimated that if only six per cent of the country's motor fuel were made by this process, the by-product ethyl alcohol would about equal the present total consumption of alcohol in the U. S., and would glut the market. The chemical companies are probably not worrying too much about this threat because not many plants can be built for natural-gas conversion. Such a plant, to pay out an investment, must be located in an area containing huge concentrations of cheap natural gas and an abundance of fresh water. There are not many places that satisfy these requirements. And it will be many years before a substantial part of our motor fuel is made from coal.

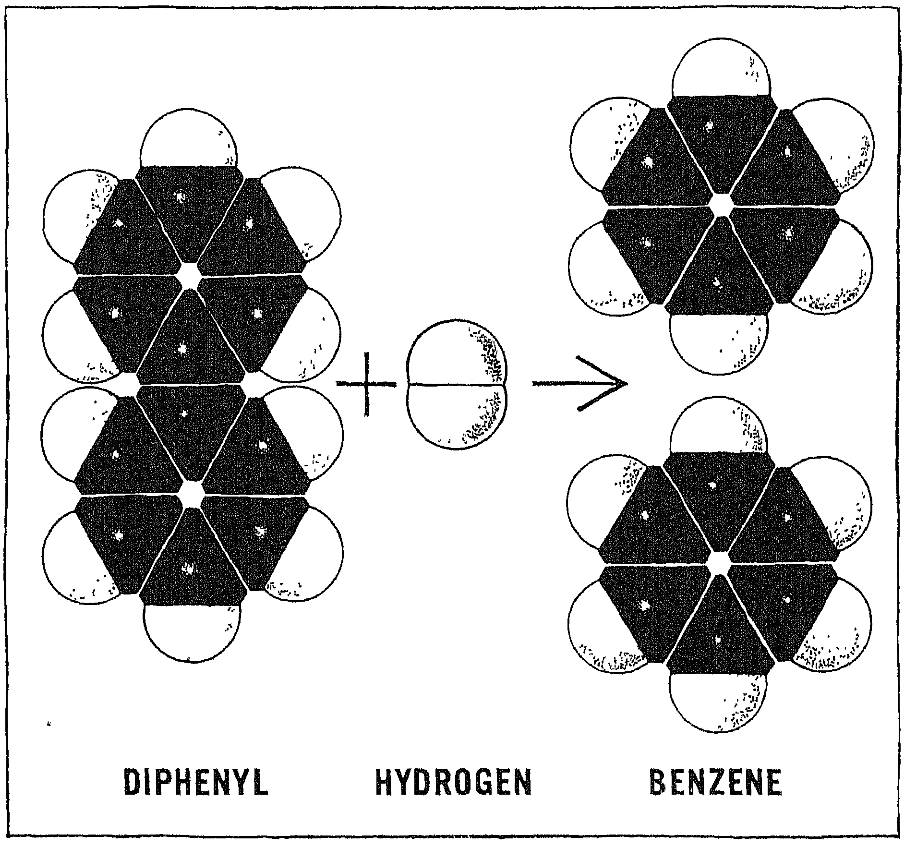
The Fischer-Tropsch process undoubtedly will grow in importance to our fuel economy as time goes on. Ultimately it may play a huge role in the cleanup of our fuel resources. Much of the coal in the ground will never be minable. Much of the oil-shale contains too little hydrocarbon to justify handling. When our oil fields are "exhausted," great *quantities of oil, unrecoverable by ordinary* methods, will still remain in the earth. There will also be large quantities of oil in inaccessible deposits of tar sands. The time may come when the gasification processes associated with Fischer-Tropsch will be used as scavengers to recover these precious residues in the form of synthesis gas. A little work has already been done on underground gasification. The projects have been clumsy and unrewarding, but technologists are not overlooking the eventual necessity of "the last roundup."

The technologists of industry and government deserve the highest praise for their active exploration during the past few years of the many intricate phases of the fuel problem. Much of their valuable work will not be used this year or next, but the time will come when we will find in it the means for survival.

Eugene Ayres is director of the chemistry division in the Gulf Research and Development Company.



IN NONDESTRUCTIVE HYDROGENATION hydrogen is added to an unsaturated hydrocarbon molecule to make a saturated one. The hydrocarbon model at the left has two carbon atoms at the bottom with valences unfilled by hydrogen atoms. In the model at the right the valences have been filled.



IN DESTRUCTIVE HYDROGENATION a larger molecule is broken down to smaller ones by the addition of hydrogen. Here there is a reduction instead of an increase in molecular weight. This process is speeded only moderately by catalysts, while the other often cannot proceed without them.

VISIT TO POLAND

The author travels to the land of his birth and makes a tour of some of its ruined but reviving universities. Last in a series of three articles

by Leopold Infeld

I WENT to Poland at the invitation of the Ministry of Education to lecture on theoretical physics at its universities and to acquaint myself with the Government's plans for the organization of higher learning. I looked forward to the visit with longing, and also with dread. Poland is the country of my birth. The longing for the country of one's childhood is the longing for youth. Yet Poland is not only the land of my youth, it is also a land of death. There my family, including my younger sister, whom I loved most dearly, was murdered by the Nazis. I do not even know in what manner they died.

Before I entered Poland, I made an important resolution to which I adhered. I decided that if I did not like something about the country I would tell my hosts about it first, and not save my impressions until I had left. This resolution proved to be a happy one. At first I did not feel that I received the full confidence of the Polish officials, but as I talked freely about the things that I liked and disliked, I experienced the pleasant realization that confidence in me increased. Indeed, the Poles were more interested in my criticisms than in my praise The higher officials in the Ministry of Education often argued with me, explaining why certain things were done for historical or ideological reasons, but they seemed grateful that I did not come to them with platitudes of approval or dogmatic disbelief.

When I arrived at the Warsaw airfield, two gentlemen were waiting for me. One introduced himself as the under-secretary in charge of universities and research in the Ministry of Education, a Mr. W. Michajlow. He greeted me in the name of his Ministry and introduced the other man, whom I later called "my guardian." He is assistant to the chair of theoretical physics in Warsaw University, and he had a leave of absence for a month to be my escort throughout my visit.

We got into a car to drive to my hotel. I remember well the old Warsaw, where I lived more than 20 years ago. Now we drove through the remnants of streets and past skeletons of buildings more thoroughly ruined than those I had seen in Berlin. My companions told me the names of the streets we passed. I remembered the names well, but could not recognize the streets. Yet Warsaw was much less depressing than I had anticipated. In Berlin I had seen dead people walking on dead streets, in Warsaw, the people were wonderfully alive. The streets were overflowing with them. They were dressed modestly, yet with a certain elegance that comes not from wealth but from a natural dignity. Workers, women and officers stood in orderly lines waiting for streetcars—a strange sight to one who knew only the old Poland. When we came to Nowy Swiat (New World), one of the principal streets of old Warsaw, I felt greatly cheered. Now largely rebuilt, Nowy Swiat and its prolongation (called Stalin's Alley) is almost as beautiful as it ever was.

I had a comfortable room with a large bath in Warsaw's best rebuilt hotel, the Bristol. The hotel houses a number of embassies and legations, among them the Canadian Legation, where I later had several pleasant visits with the Canadian chargé d'affaires, the distinguished poet Kenneth Kirkwood.

Michajlow discussed with me the itinerary for my visit. He urged that I give as many lectures as I could, in Warsaw and in other university towns, and asked me to study the Ministry of Education's new plans for graduate and undergraduate teaching in science, especially in physics and mathematics. He suggested that I begin by visiting the Warsaw University physics laboratory next day and have a talk with its head, Stefan Pienkowski, a former rector of the University. Michajlow told me that my escort would visit me every morning to arrange appointments for me with whomever I wished, and that a car and chauffeur were at my disposal for my stay in Warsaw. Moreover, my hotel bill and expenses in Warsaw were to be paid by the Ministry.

Michajlow, as under-secretary in charge of universities, did not at first strike me as a very spectacular person, but I became more and more impressed with him as time went on. Tactful, understanding and a very hard worker, he turned out to be one of the most intelligent and devoted civil servants I have ever met.

My escort, it soon developed, was practically indispensable. Telephones are so rare in Warsaw that whenever I wished to see anyone I had to ask my escort to go trotting off to make an appointment for me. This was the case even when I wanted to visit officials at the Government offices, for their telephones were almost constantly busy. My faithful escort contributed greatly to the comfort and efficiency of my visit.

The third man whom I met daily, my chauffeur, was my only close contact with "the people " A witty man with no great interest in politics, he talked to me by the hour about Warsaw. He knew every neighborhood of the city—how it looked two years ago, and how it will look 10 years from now. He showed me the sites of the bloodiest fighting during the war. He had taken part in the Warsaw uprising, and knew the history of every building, almost of every stone. This, I discovered, was typical of Warsaw citizens. Their city is not merely a town they live in, but like a woman they love. Even those who severely criticize the Government grant it one great virtue: it is rebuilding their beloved town. No one can fail to be impressed with the job done by the Polish Government in rebuilding its capital.

MY first call in Warsaw was on Mme. Z. Korman, a good friend whom I had last seen some 20 years ago. A war widow, she is now a professor of history at Warsaw University, and it was she who had taken the initiative in having me invited to Poland. To reach her home we had to pass through the Jewish Ghetto. Where once some 300,000 people lived, nothing now remains except acres of weed-grown rubble, without the slightest trace of a wall or building. The only signs of life in this void are a streetcar line and road cutting through it and a monument erected to the fighters of the Ghetto, with two Polish soldiers guarding it. Nothing that I have ever seen was

as expressive of human suffering as these acres of rubble. It is the intention of the Polish Government never to build up this place. It will remain forever a monument to human degradation—and heroism.

Shaken by this experience, I was relieved when we arrived in the suburbs, now rebuilt with huge modern apartment houses, where Mme. *Korman lives.* Except for the lack of a telephone, her attractive apartment had all the conveniences that a professor in North America would have. I found that in general university professors in Poland live comfortably. I believe this would not be equally true of people in other occupations Professors, writers and artists are the new aristocracy in Poland; their standard of living is higher than that of physicians, lawyers or even important Government officials. Scientists live well because food and apartments (assigned by the Government) are cheap, and because they have an almost unlimited opportunity to increase their earnings by writing books and articles. Their writings are in great demand because the libraries were burned and textbooks destroyed.

It would be incorrect to say that all the intellectuals in the universities are enthusiastic supporters of the present Government. Many are not. Yet not one professor has been dismissed, no matter how well known his critical or hostile attitude. The reason for this is both the need for professors and the Polish tradition of appreciation of scholarship and intellectual achievement.

Next day I visited Professor Pienkowski's physics laboratory at Warsaw University. I have always liked Pienkowski, a lively, able man and excellent administrator who, in the prewar years when Polish academic life was saturated with anti-Semitism, was fair and decent to Jewish students. I owe at least partially to him the Rockefeller Fellowship for which he recommended me. I had not seen him for 15 years. He is now in his 60s, but I did not detect much change in him, he is as vigorous as ever

I asked Pienkowski what had happened to his Institute during the Nazi occupation To understand his story, it is necessary to know some background. Before the war Pienkowski's laboratory was one of the best equipped in central Europe, and was known throughout the world for its work in spectroscopy. The prewar government enlarged the University's physics building, and the Rockefeller Foundation gave a generous sum for scientific equipment. About five years before Hitler's invasion of Poland, an international conference on fluorescence and spectroscopy was held at Warsaw University. I attended the conference, and saw there many German scientists who delivered lectures and, with other guests, were guided through the laboratories and shown all the scientific equipment. After the fall of Warsaw in 1939, the laboratory, which had escaped bombing, was promptly visited by a German educator, a General Schuman. He had a complete list of its equipment, and announced that all the instruments would be taken to Germany. He tried to persuade Pienkowski to go to Germany, offering to set him up in an institute at least as good as the one at Warsaw. When Pienkowski refused, the General predicted: "Grass will grow here; Warsaw will be a village." Soon afterward staffs of German experts came and methodically removed all the research equipment, teaching materials, even the furniture. It was all done with truly German thoroughness, according to a careful plan prepared well in advance. To Pienkowski's pleas the German educators replied: "We must do it, even if we lose the war we must make it harder for Polish science to rise again."

None of this equipment was recovered by Poland after the war Pienkowski told me: "The Polish reparations commission could not find any of it, and I have given up all hope"

STEFAN PIENKOWSKI of Warsaw University directs physics laboratory known throughout the world before the war for its work in spectroscopy. Pienkowski attended Operation Crossroads at Bikini Atoll as an observer.

IF you multiply this despoliation by a factor of 1,000, you can understand what happened to Polish education during the war. No university or high school was permitted to function. University professors became janitors or white-collar workers; many were killed. Nevertheless, Poland's educators did not give up. The entire high-school and university system went underground, and all the teachers and professors taught secretly, besides working at the manual or desk jobs that saved them from starvation. Pienkowski was the chief organizer of the underground universities. The clandestine classes were restricted to 10 students each, and every month the meeting places were changed.

When Pienkowski returned to his laboratory in 1945, he found that the building had been used as offices for a German transportation commission; the Germans left only broken walls, windows without glass, not one book of the once splendid library, a single lonely table. With magnificent courage Pienkowski and his colleagues started all over again. First they hired six carpenters, salvaged sticks of lumber wherever they could find them, and built some furniture. The Provisional Government of Poland gave them permission to collect teaching equipment

from the excellently equipped German high schools that the Nazis had established in Poland. Through Poles in the U. S. and through a British group Pienkowski's laboratory obtained some books. The Soviet Academy of Sciences sent one precision spectroscope as a token of friendship. When the Polish state became organized, the new Government supplied costly precision apparatus, some bought in Switzerland, some in England. Pienkowski told me that the postwar Government's spending on the Institute has been considerably higher than even the generous support it had from governments before the war. His laboratory, now building a Van de Graaff generator to accelerate atomic particles, is again a going concern.

When I gave my first lecture at Warsaw University (in Polish, in which I had difficulty at first with the technical terms), I was astonished and impressed by the level of knowledge among my audience. Many of the graduate students were as familiar with modern physical theories as those at any good university on this continent. They had acquired their knowledge from books and papers rather than from lectures, since there are very few theoretical physicists in the older generation in Poland. Among them the most distinguished is W. Rubinowicz, a pupil of Niels Bohr He is now a professor at Warsaw, leading the only school of theoretical physics in Poland worth mentioning. In the past few years Rubinowicz has sent brilliant students to France, England, Switzerland and the Netherlands to complete their graduate studies, a fact that emphasizes Poland's desire to keep its scientific ties with western Europe.

FROM Warsaw I went on to visit two other universities—Wroclaw and Cracow. As we flew over Wroclaw, formerly the German town called Breslau, the center of the city presented an unbelievable sight. It looked as if a child had set out models of buildings to form a town, and then had trampled on it with angry feet Hardly a house had a roof. After Warsaw, Wroclaw seemed lifeless and depressing. It had always been an ugly, graceless German town, and there is no noise of rebuilding there, nor the active life of Warsaw. The restoration of Warsaw has priority over all other towns.

Wroclaw University is in effect a transplantation of the old Lwow University, where I taught in my younger days. The town of Lwow is now inside the U.S.S.R., and its university and professors were transferred to Wroclaw. Because many of the professors were my former colleagues, I looked forward to this visit with nostalgia. Like many revisits to old stamping grounds, it turned out to be rather depressing. During my absence, I must have become sensitive to many things that had sounded natural to me when I lived in Poland. One of them is the mania for titles. Lwow used to be especially hard-ridden by this mania, having inherited it from the period when it was part of the Austro-Hungarian Empire. The obsession lives on in Wroclaw, and to a lesser degree in the rest of Poland. At Wroclaw the official title of the rector is "his magnificence." After hearing "Mr. Magnificence" repeated every few seconds, it is hard to retain one's self-control.

The University's strong point is mathematics Polish mathematics was world-famous before the war, but it suffered greater losses than any other science. Many mathematicians were murdered for being Jews; some died of hunger and exhaustion; some committed suicide. Polish mathematics is still good, but it is not what it was. What remains of its former greatness is concentrated in Warsaw and Wroclaw.

I went from Wroclaw to the most beautiful city on earth—Cracow. It is the town where I was born and from which the members of my family were led to death Physically nothing of Cracow was destroyed. Its parks are full of flowers and green, its people are well dressed. The reception I received in my native town was the most touching experience I have ever had I lectured in the huge auditorium in the physics building, in the same room in which I had listened to the lectures of my former teachers. The lecture had been announced by radio, and the room was full half an hour before I began to speak. People with whom I had gone to public school as a child came to shake my hand and to tell me that they were still alive. The applause when I entered the room, and after my lecture, was warm and loud.

Professor H. Niewodniczanski and his wife were my hosts. I knew them well, for we had spent a year together at Cambridge University on Rockefeller Fellowships. Again I heard the story of how an empty building became a physics laboratory. This time the story had a peculiar twist. At the end of the war, German marks became almost worthless, but laboratory apparatus in Germany was still listed at the low prewar German prices in marks. Thus it was theoretically possible to buy them from German factories for practically nothing, if one could convince them to sell. Niewodniczanski and a colleague had an idea. They requisitioned three trucks from the Polish Government and drove to factories making scientific instruments in Germany. At each they staged the same performance. The director of the factory would say that all the equipment in stock had been ordered by German schools and universities and there was none for sale. Then Niewodniczanski would take out a package of cigarettes or a pound of bacon. The director's eyes would glitter, and he would change his tune immediately. He would be ready to sell anything at the list price in almost worthless marks. For a few hundred dollars the professor bought enough equipment to outfit the entire University

BACK in Warsaw, I was kept busy lecturing, seeing people, and conferring with officials of the Ministry of Education on the plans for reorganization of the Polish universities I found this a most interesting problem

Continental European universities are rooted in the Middle Ages. In Poland, as in Germany, the universities before the war, though functioning in a country that was far from democratic, were more democratic in form than any university in America. While they were nominally under the supervision of the Ministry of Education, actually they governed themselves according to their own laws. The faculty members chose their own rector (president) every three years, and a dean every year A professor was as independent as a king. Departments were unkown; there were only independent chairs. Every professor had his own "Institute," his own assistants. Appointments and promotions were made by the faculty on the recommendation of a committee especially elected for the purpose Even if a murder was committed on the campus, the police could come in only if called by the rector. Yet democracy in these satrapies was only a form. In spite of their democratic structure, the universities in Poland were more socially backward, more anti-democratic than the rest of the country

Immediately after the war they were rebuilt in the old tradition. Although their superficially democratic character was thus retained, this system of organization lacked the fundamentally more democratic machinery for cooperation that exists in a modern university. The Ministry of Education also made other grave mistakes. To staff all the old universities and new ones that it had to build, it spread the depleted teaching staff too thinly The result was a decline in the level of research and teaching and a wasteful scattering of forces In a provincial university there would be one good man, say in physics, with no graduate students, no equipment, no other physicists to talk to

I found the Ministry officials entirely ready to admit the mistakes and busy correcting them. They had already planned a process of integration and the creation of centers of research. Their plans for reorganization will bring the Polish universities nearer the American, English and Canadian models.

THE headquarters of the Ministry of Education in Warsaw was one of the very few buildings that survived the war. The Ministry owes this piece of good luck to the fact that its modern,

attractive structure was occupied by the German Gestapo. I ended my visit to Poland with a lecture in this building before some 50 professors, officials and guests of the Ministry. I discussed features of Canadian education which I thought should be adopted, with certain modifications, by Polish universities. One was the division of faculties into departments, another that a clear distinction be made between graduate and undergraduate education, a distinction which is almost unknown on the European continent. I also urged the need for reducing the bureaucracy in university administration. Indeed, one of the worst things that I found in Poland was the great amount of red tape, in and out of the universities. The Polish officials explained the reason for it. While the personnel at the highest levels is usually intelligent and skillful, below these ranks competence drops sharply. There is a tremendous lack in all branches of life in Poland of qualified, well-educated people. The mediocre civil servants, afraid of making decisions, pass papers up to higher levels, where they grow into mountains. The higher government officials work 12 and often more hours a day, because everything from below, from the trivial to the important, is loaded on to them. Secretarial help at the universities is practically unknown. The Ministry vows, however, that in time all this will be changed

YET comparisons are not all to the disadvantage of the Polish universities. Things that would be difficult to accomplish in Poland are easy in America, but the reverse is also true. It would be difficult for me to obtain four new assistant professors in our department at the University of Toronto; in Poland it would be comparatively easy, provided the right people could be found.

European universities in general are remarkably allied in spirit, fantastic as this may sound to anyone who does not know Europe. In spite of the great differences between Ireland, England and Poland, in their attitude toward scholarship and intellectual achievement these countries are much closer to one another than any of them is to America.

For all its poverty in material and human resources, Europe has something which we do not have, and which all the splendid scholars who have come to this continent have not been able to kindle. It has greater curiosity and greater enthusiasm for learning. While the flame of learning burns more dazzlingly here, in Europe it sets fire more widely to the imagination of the people.

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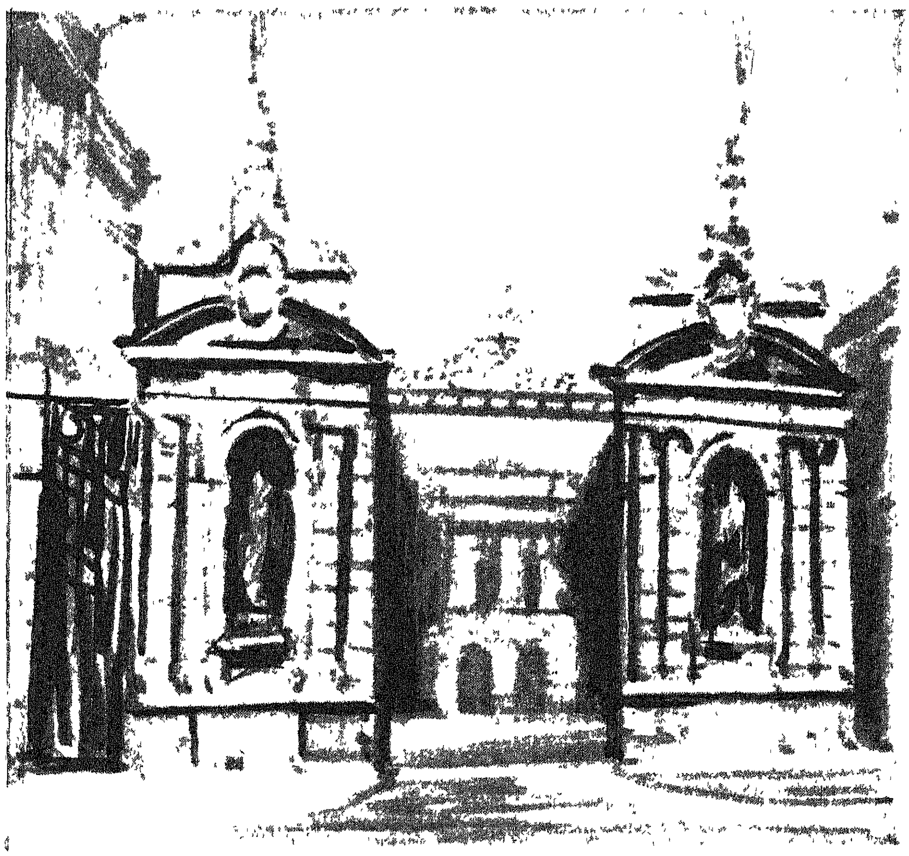
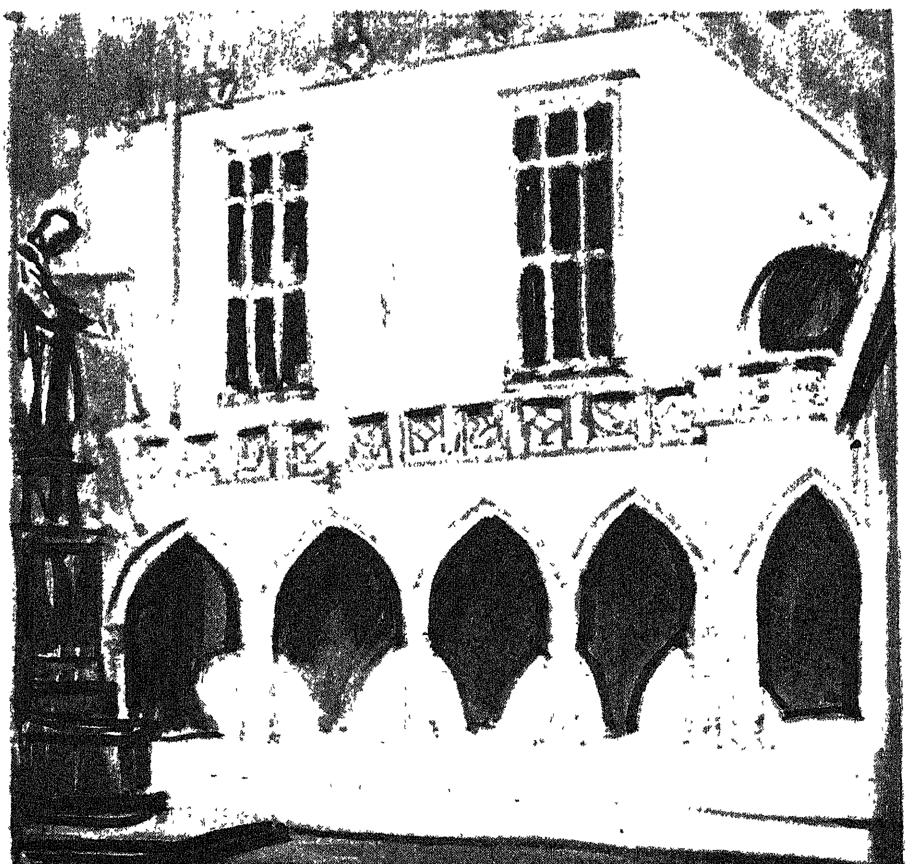


WARSAW UNIVERSITY'S gates still stand after the German occupation. During the war the occupying forces removed all the equipment from the physics laboratory and used it as an office for a transportation commission.

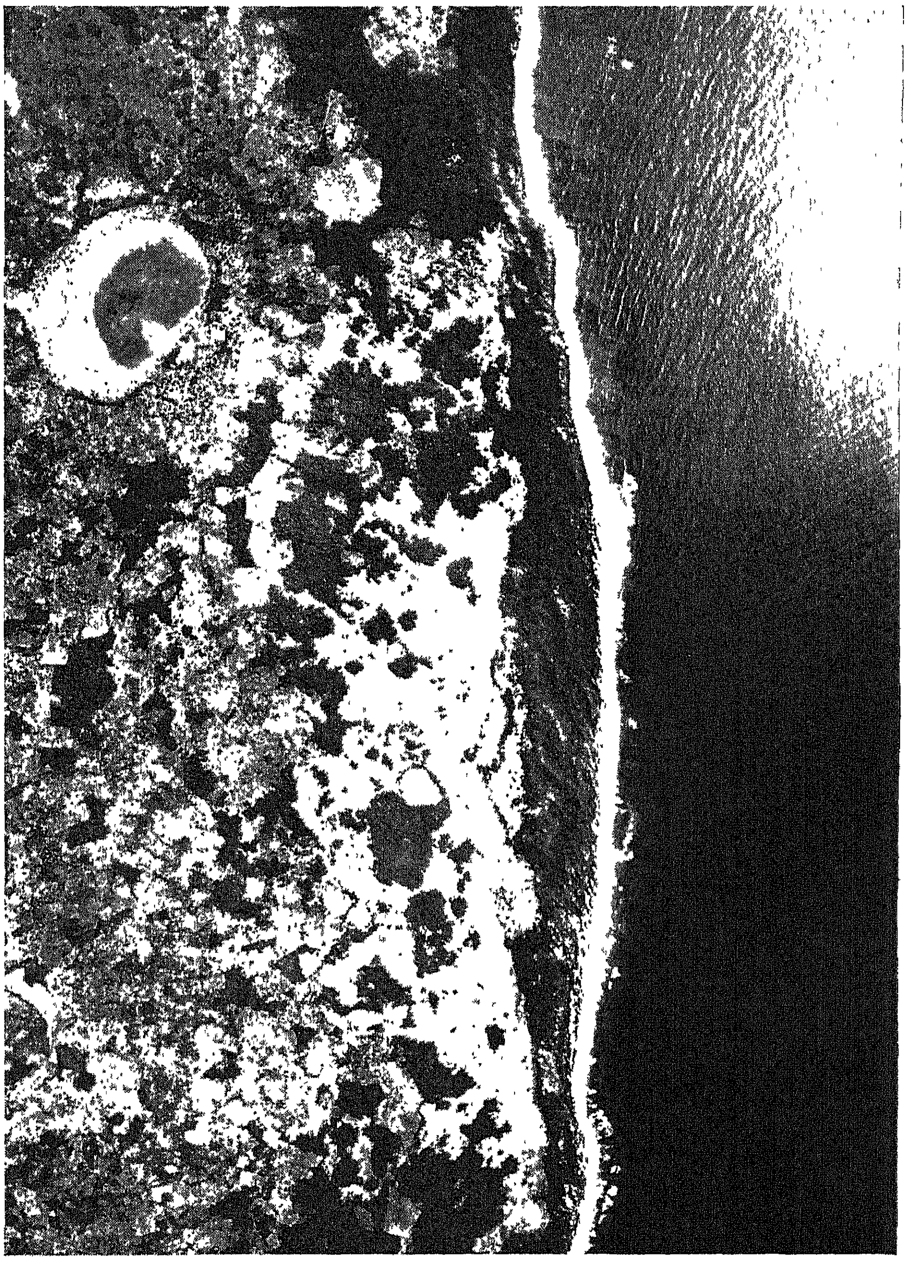


CRACOW UNIVERSITY library, like the rest of Cracow, was not greatly damaged by the war. The university, second oldest in central Europe, was founded in 1364. At left is a statue of Nicolaus Koppernigk (Copernicus).

FLOOR of coastal waters is visible in right half of photograph made from 15,000 feet. On land are small farms (*bottom, left*), almost dry lake beds (*left center*) and a 1,500-foot airstrip (*top*). The water is still and clear. Height and direction of the sun are indicated by shadows on the bottom. The photograph is unretouched.

OCEAN'S FLOOR

A remarkable aerial photograph uncovers its conformation off the coast of Africa



SURFACE of the sea in the same region normally is ruffled by the wind. This plus the glare of the sun, a diffuse reflection of which appears at the upper right, makes the surface an efficient reflecting and light-scattering device.

THE bottom of the ocean, some of which is wrinkled into features as rugged as those of the land, is occasionally visible from the air. Such a rare moment was recorded last summer by the aerial mapping camera of a plane flying three miles above the coast of Portuguese East Africa. There the bottom of a still inlet of the Indian Ocean could be seen with startling clarity. The plane was operated by the Aero Service Corporation of Philadelphia, which was making a survey of the 47,000-square-mile concession area of a subsidiary of the Gulf Oil Corporation. Aero Service made a complete aerial map of the area, then its plane flew a precise pattern over it bearing an airborne magnetometer. This sensitive device, developed during the war to detect submarines, continuously records variations in the earth's magnetic field and thus provides information about geological structures concealed beneath the surface of the land. The magnetometer record is synchronized with photographs from a continuous-strip camera, which makes it possible to correlate the magnetometer data with the aerial map. The final product is a complete magnetic map of the region.

MAGNETOMETER hangs in a bomb-shaped case beneath the DC-3 from which the photograph on the opposite page was made. Plane was used first to make aerial map of the region, then to survey it for variations in magnetic intensity. On the ground below are the waste sludge piles of gold mines in the Union of South Africa.

Crystals and Electricity

In certain crystals mechanical deformation liberates electric charges, and vice versa. This piezoelectric effect has many applications, notably in ultrasonics

by Walter G. Cady

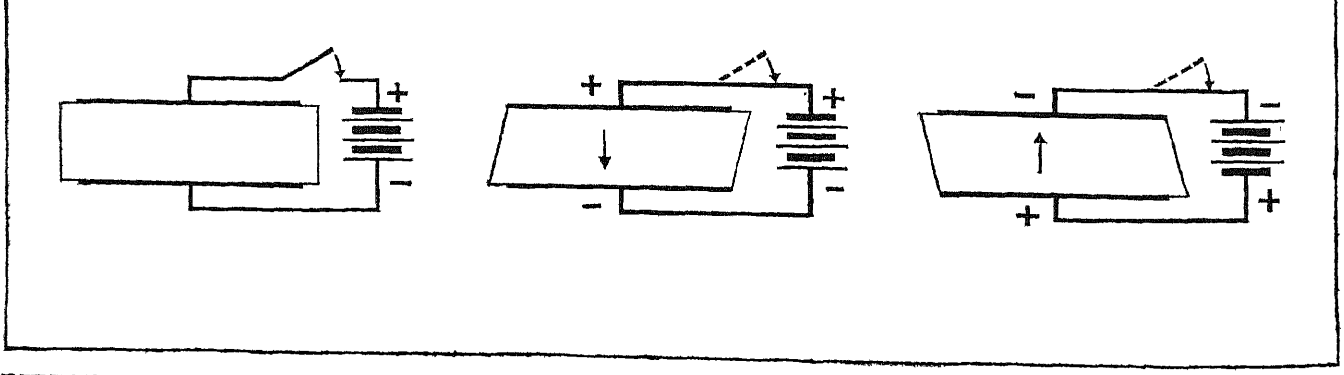
PIEZOELECTRICITY (pronounced pie-*case*-o-electricity) is a Greek-derived word meaning "pressure-electricity." It is the name of an effect produced in certain types of crystal that can convert mechanical energy into electrical energy. Mechanical pressure applied to such crystals liberates electricity. For example, if a strongly piezoelectric crystal such as Rochelle salt is connected by means of electrodes to a neon lamp, a tap on the crystal with a hammer will liberate enough electric charge to make the lamp flash.

Piezoelectricity has become in recent years a very fertile field for research, not only because it has a great many useful applications but also because it is a means for fundamental studies of the structure of matter. Electrical effects, as is well known, can be produced in matter in various ways. by heat (thermoelectricity and pyroelectricity), by the action of light (photoelectric effects); by chemical action, as in a battery, and by several types of application of mechanical forces, of which the most familiar is the dynamo. In general these effects are more or less reversible: *i e.*, electric currents can produce heat, light, chemical reactions and mechanical motions. Piezoelectricity belongs in the class of electromechanical phenomena and, like the other effects, it also works two ways. Just as mechanical pressure on a crystal can produce electricity, so an electric current applied to the same crystal can produce mechanical motion

The piezoelectric effect was discovered in Paris in 1880 by the brothers Pierre and Jacques Curie. They had long been interested in crystallography. They knew that some crystals, such as rock salt, are highly symmetrical, while others show a low order of symmetry. They conceived the idea that certain types of asymmetrical crystals might, when compressed in certain directions, liberate electric charges, positive on one side, negative on the other; in other words, that such crystals would become electrically polarized when compressed. They verified their prediction by tests with a large number of crystals of different kinds, including quartz, tourmaline and Rochelle salt.

In view of the fact that all matter consists of positive and negative electrical particles, it need not seem surprising that deformation of a solid should produce a displacement of electric charges. But why is it that only asymmetrical crystals show the effect of this displacement? The reason is that in noncrystalline materials and in the more symmetrical types of crystals the charges do not tend to be displaced in opposite directions. Therefore pressure produces no external electrical effect in them. On the other hand a crystal of low symmetry has a single-track mind, or at least a one-wayness in its internal structure. Although its atoms, and the bonds between them, are arranged just as regularly as in crystals of higher symmetry, their arrangement is such that when a pressure is applied in the proper direction, positive electricity is "squeezed" in one direction and negative electricity in the other. Of the 32 classes of crystals known to crystallographers, 20 have enough lack of symmetry to be piezoelectric. Technically speaking, they all lack a "center of symmetry."

THE liberation of electric charges from a piezoelectric crystal by mechanical pressure is called the direct effect, and the change in shape produced by an electric current is called the converse effect. The latter has various forms. Suppose that a flat slab cut from a piezoelectric crystal is placed between two flat metallic electrodes connected to a battery. The battery voltage will cause the slab to be deformed or "strained," the amount of deformation depending on the battery voltage, among other things. One type of strain, called a "shear," changes



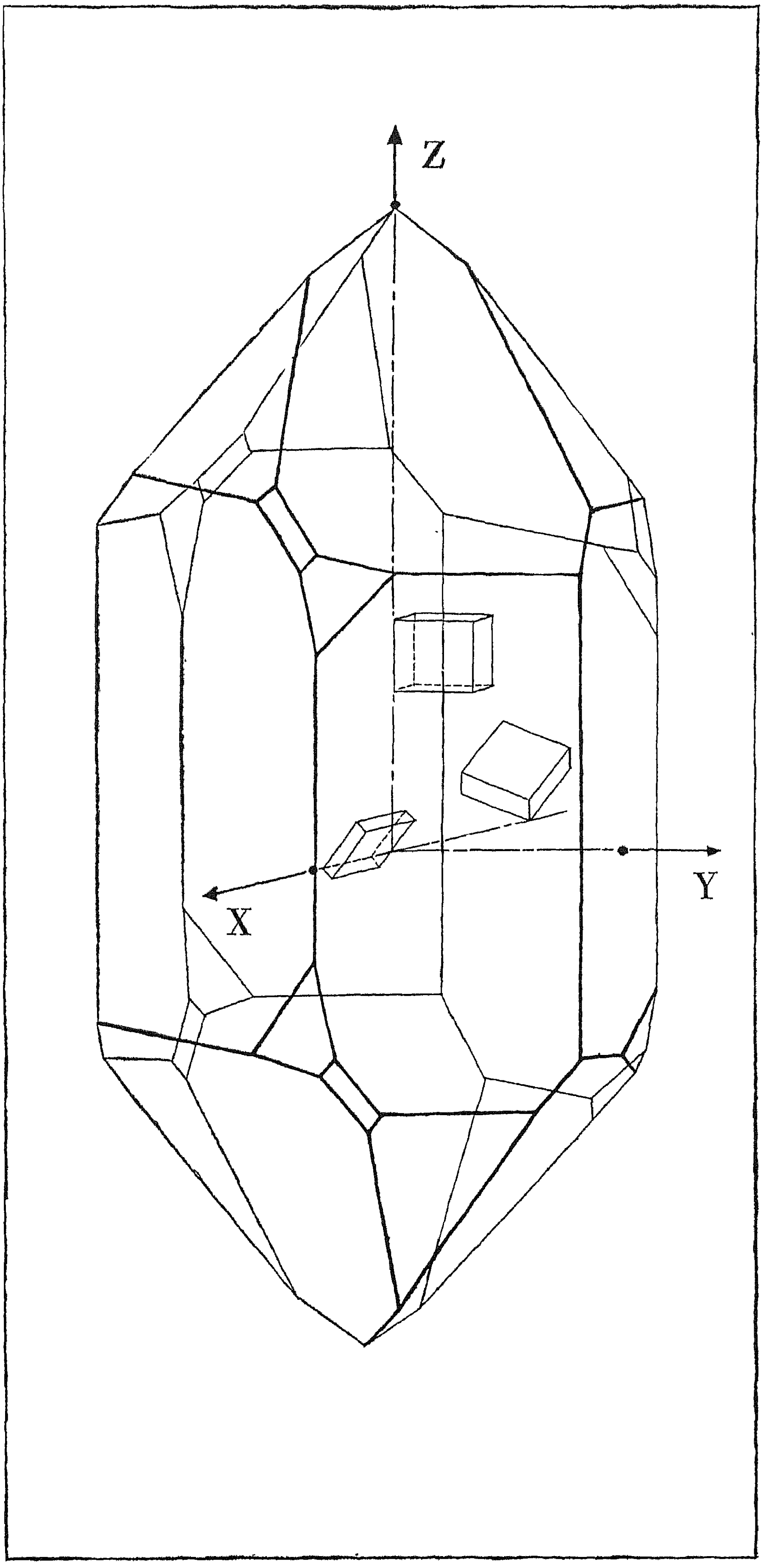
PIEZOELECTRIC CRYSTAL is placed between two metal plates connected to a battery. When circuit is closed (*center*), rectangular cross-section of crystal is deformed into a parallelogram. When current is reversed (*right*), deformation is reversed. In this diagram degree of deformation has been exaggerated for clarity.

the shape of the crystal slab from a rectangle to a nonrectangular parallelogram (*see drawing at the bottom of opposite page*). A reversal of the battery voltage reverses the direction of the shear. In other types of crystal the deformation is different: the slab remains rectangular but is made longer and thinner by an electric field in one direction, shorter and thicker by a field in the other direction. When the battery is replaced by an alternating-current generator, the slab vibrates with a certain amplitude of motion. In the first case described above the vibrations will be in a "shear mode," with the top and bottom surfaces shuffling back and forth; in the second case the slab will become alternately shorter and thicker, and longer and thinner. All these deformations are far too small to be seen by ordinary means, but there are several ways by which they can be measured.

Crystals can be classified according to their axes, or the directions in which their atoms are arranged. When an engineer is given a new type of crystal that may have useful piezoelectric properties, his first question is, "Where do the axes lie?" The axes of several types of crystal, as well as typical outward forms, are shown in the drawing at the right and in those on page 48. Among the most useful piezoelectric crystals, some of which are illustrated in these drawings, are quartz, tourmaline, Rochelle salt, ammonium dihydrogen phosphate (ADP), ethylene diamine tartrate (EDT), lithium sulfate and barium titanate. From each type of crystal the engineer makes characteristic "cuts" of slabs or bars, the cut depending on the purpose for which the crystal is to be used. Very often the cut is at right angles to an axis, since in most piezoelectric crystals an electric field parallel to any one of the three axes causes a deformation. In some cases the deformation is a shear, in others it is an elongation in one direction with a contraction at right angles, in many cases both types of deformation occur together. For some special purposes the slabs are cut at oblique angles to the axes, such cuts may be piezoelectric because the field has components parallel to at least two axes.

Let us consider now the applications of the piezoelectric effect, and in particular the part played by crystals in the field of ultrasonics.

THE first attempt to apply piezoelectricity was made during World War I. The famous French physicist Paul Langevin conceived the idea of using an electric current to make quartz plates vibrate so as to send out a beam of ultra-audible sound waves under water for locating submerged submarines. The distance and direction of the submarine were to be determined from the echo returned from the craft's hull and de-



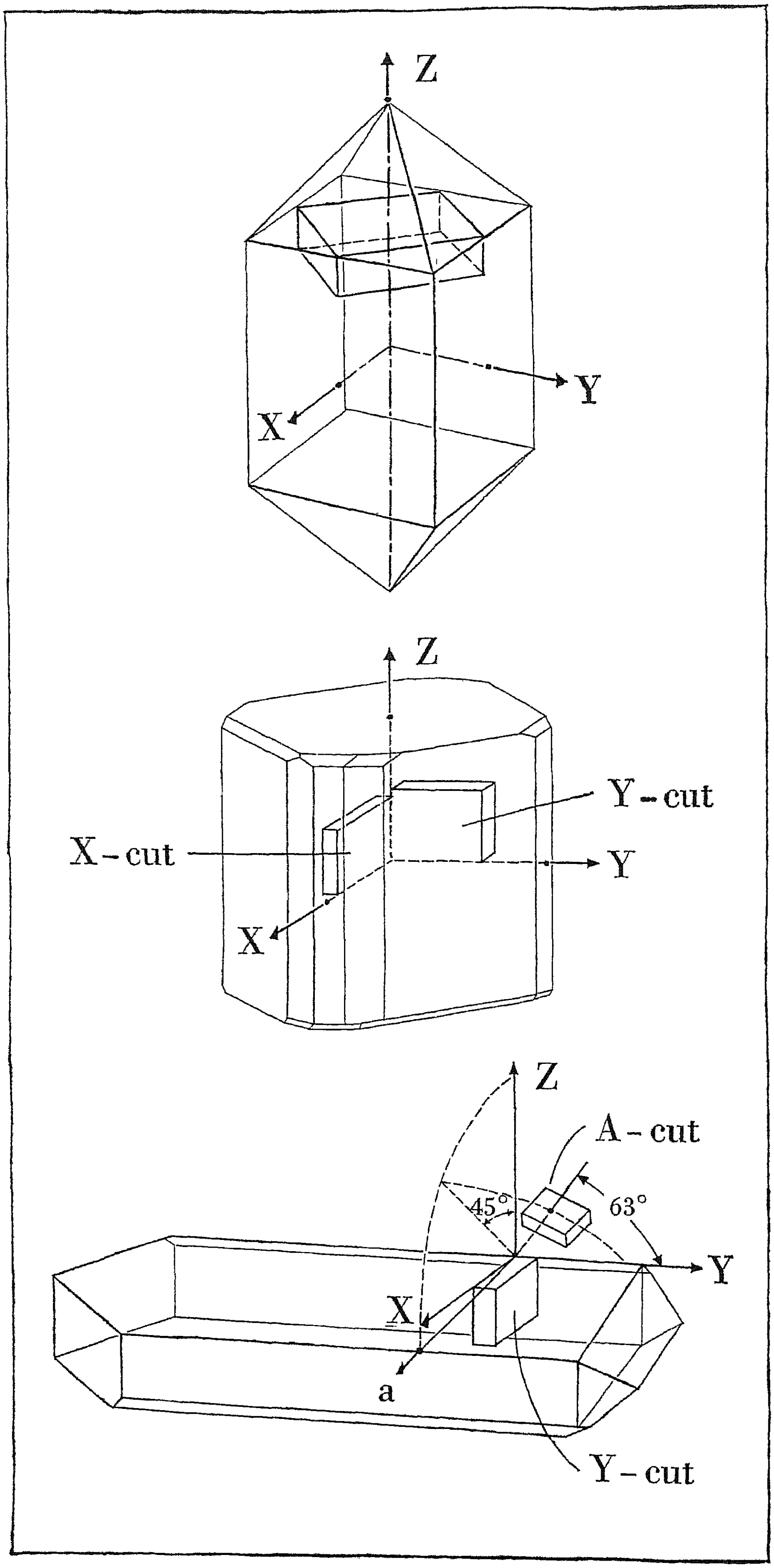
NATURAL CRYSTAL of quartz has three axes at right angles to each other. They are designated the X, Y and Z axes. Three common "cuts" related to these axes are indicated here by the small slabs that are within the crystal.

tected by the same system of crystals that emitted the waves. Except that it used sound waves instead of radio, this system was exactly parallel to radar, which was to be developed in World War II. Langevin's invention was immediately recognized by the Allies in World War I as a hopeful solution of the problem of detecting submarines. Intensive research to this end was carried on in the U. S. and in England. Although no extensive military use was made of these detecting devices during the First World War, crystal research was continued afterward in many laboratories, and by World War II piezoelectric crystals played an important part, not only in detecting enemy submarines and mines, but in radio and radar as well. The system based on Langevin's invention became known as sonar.

Crystals have now come into use in all forms of electrical communication—the telephone, telegraph, the phonograph, television. A familiar example is the crystal pickup for phonographs. Here two thin plates of Rochelle salt or ADP (more recently, ceramic plates containing barium titanate crystals) are cemented together face to face and provided with electrodes connected to an amplifier and loud-speaker. The needle on the rotating record is attached to these plates, and its vibrations cause the plates to be slightly deformed. These deformations in turn liberate electric charges which are amplified and actuate the loud-speaker. Another example, using the converse effect, is the crystal headphone. Here the crystal acts like an electric motor, converting electrical into mechanical energy. Various devices employing the same effect have been invented for recording variations in electric currents. They include a crystal cardiograph and a crystal oscillograph.

Some of the important applications are based on the fact that a crystal, like most other vibrating bodies, has a number of natural frequencies. Like a musical instrument, it has a fundamental frequency and higher "harmonics," sometimes hundreds of them. When the alternating current flowing to a crystal has a frequency identical with one of its natural frequencies, the vibrations become most intense. The crystal is then said to be "in resonance." The strain produced by such a resonance may become great enough to shatter the crystal, just as a powerful singer's voice can shatter a resonant glass.

Resonant crystals, known as piezoresonators, generally use the ultrasonic frequencies, far above the range of human hearing. Crystals can be made to vibrate in resonance at frequencies as high as 200 million cycles per second, with a vacuum tube generator as the source of the alternating current. The various modes of vibration are shown in the drawings on the opposite page. For



ARTIFICIAL CRYSTALS may also be piezoelectric. The three shown here are grown from saturated solutions in water. They are ammonium dihydrogen phosphate (*top*), Rochelle salt (*middle*) and ethylene diamine tartrate (*bottom*). The X, Y and Z axes of each and some common cuts are shown.

the lowest frequencies narrow crystal bars a few inches long are so driven electrically that they vibrate by bending, like the metal plates of a xylophone. For frequencies from 30,000 to 300,000 cycles per second, a plate or narrow bar is made to vibrate so it either becomes alternately longer and shorter, or oscillates in a shear mode. The author has observed resonance at about 1.5 million cycles per second in a quartz bar that was only 1/16-inch long. For frequencies above 300,000 cycles it is customary to use plates in "thickness vibration," the plate becoming alternately thicker and thinner. For radio circuits the "thickness shear mode" is preferred.

IN some of the most important applications the direct and converse effects are combined. Here the crystal is set into vibration and driven as a motor by an alternating current. The vibrations are not used for doing mechanical work, but rather, through the piezoelectric charges liberated by the direct effect, to control the alternating current that drives them, just as the counter electromotive force generated by an electric motor has a regulating effect on the supply current. A feature peculiar to the crystal, not present in ordinary motors, is that the intensity of vibration (corresponding to the motor speed) depends, among other things, on the frequency of the alternating current applied to it. It is precisely when the crystal vibrates most vigorously that it reacts most strongly on the alternating current that drives it. This fact is made use of in radio transmitting circuits, which commonly employ quartz crystals to hold the frequency of the radio waves constant. A bit of crystal no larger than one's thumbnail can control the frequency of a powerful broadcasting station. The crystal is to the transmitting circuit what a pendulum is to a clock. (Indeed, quartz-crystal resonators are actually used to control the most precise present-day electric clocks.)

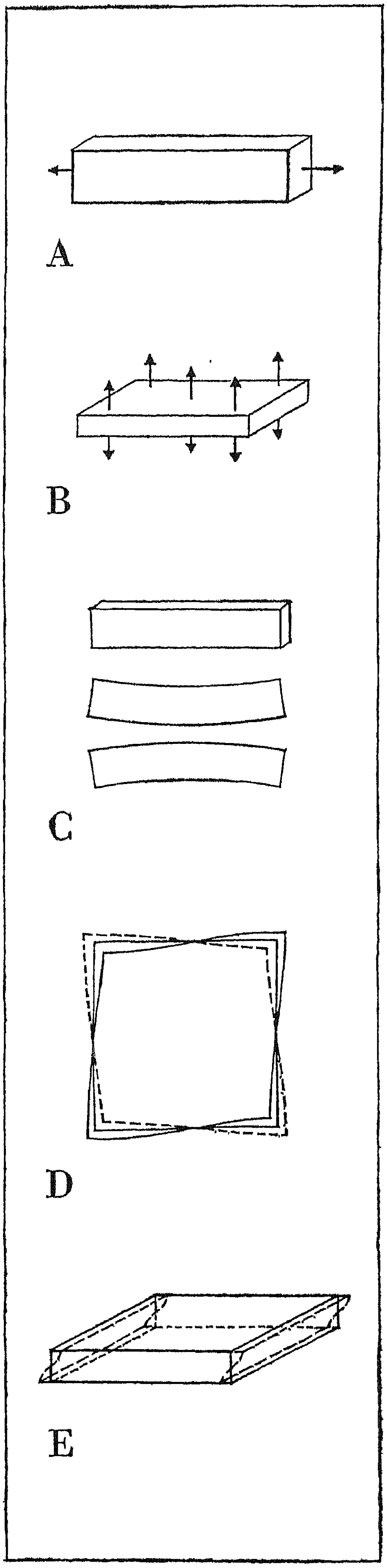
Crystals, and especially quartz crystals, can control the frequency more precisely than any other known means because their resonance is extremely sharp. By this we mean that a very small change in frequency causes a very great change in the vibrations of the crystal. For example, a quartz X-cut bar a little over an inch long and 1/25-inch thick has a natural frequency of vibration in the direction of its length amounting to 100,000 cycles per second. When it is set into vibration by an alternating current of exactly this frequency it is in resonance, and if it is mounted so as to vibrate with very little friction, an electromotive force of 20 volts will be almost enough to shatter it in pieces, although the ends move back and forth over a distance of only about six ten-thousandths of an inch. If the frequency changes by only .0005 per cent, the vibrations may be only half as great as at resonance. By good luck it happens that the range of frequencies within which crystals can be made to vibrate is the same as that commonly used in radio.

Another important application of crystals is in electric filters, particularly the "channel filters" for communication over wires. Hundreds of messages or conversations can be transmitted at the same time over a single cable by using a separate "carrier frequency" for each message. In order to unscramble the messages at the end of the line and to divert each to the desired destination there must be a separate tuned electric circuit for each message. Each circuit acts as a filter, passing a single carrier frequency while rejecting all others. The tuning must be very sharp, and crystals are superior to any combination of coils and condensers as the tuning elements in these circuits.

Quartz is employed for more different purposes than any other piezoelectric crystal. The reasons are not only that it has very sharp resonance and is mechanically durable and immune to attack by ordinary chemicals, but especially that certain cuts have vibrational frequencies which are almost free from variation with temperature. The demand for quartz crystals has become so great that already good specimens are costly and hard to obtain. This shortage is being met partly by a search for other suitable kinds of crystal, partly by growing quartz artificially. The latter art is still in its infancy. Quartz is silicon dioxide. Although it is the most abundant of all minerals, large and sufficiently perfect crystals are comparatively rare and they are found only in restricted regions, notably in Brazil.

NOW let us look a little further into what in some ways is the most interesting application of piezoelectricity—the uses of crystals as generators of ultrasonic waves. Langevin's work in this field was a pioneer investigation of a little-known physical effect. It demanded a thorough knowledge of wave motions in solids and liquids, and of alternating electric currents, plus the spark of genius. Langevin quickly obtained promising results toward the application of his findings in a submarine-hunting device. The technical difficulties were so great, however, that it took considerable effort by teams of workers in World War II to bring the device to full fruition.

When a plane surface such as the face of a crystal plate vibrates back and forth like a piston, it emits acoustic waves into the adjacent medium. Like most radiations, these waves are not confined to a narrow beam at right angles to the surface but tend to spread. They form a diverging cone of sound. The amount of divergence depends on the diameter of



VIBRATIONAL MODES of some piezoelectric crystals are (A) lengthwise, (B) thickness, (C) flexural, (D) face shear, (E) thickness shear.

the piston, the frequency of the waves and the speed of sound in the medium through which the waves pass It is possible, by a suitable choice of diameter and frequency, to produce a cone with any desired amount of divergence. For example, the speed of sound in sea water is about 4,900 feet per second Suppose that the crystal plate is made to vibrate with a frequency of 50,000 cycles per second, which means that the wavelength of the sound waves is about 1 2 inches. If the diameter of the crystal is four inches, the eventual spread of the cone, as calculated from a standard formula, is about 40 degrees of arc. By using a crystal with a diameter of 10 inches, the spread of the cone can be reduced to about 16 degrees. The cone can also be made narrower by increasing the frequency of vibration rather than the diameter of the crystal. For submarine detection the cone must be neither too wide nor too narrow. A spread of about 20 degrees has been found to be satisfactory.

Another factor that must be taken into account is the absorption of sound in the medium. Owing to internal friction in the medium, the waves die away with increasing distance This "damping" of the sound waves severely limits the distance that signals can be sent under water Damping increases rapidly with increasing frequency. For example, a beam of waves in water with a frequency of 20,000 c p.s. travels 140 miles before its intensity is reduced to one per cent of its value at the source, at 100,000 c.p s the distance is six miles; at one million c.p.s., 300 feet; at 15 million c.p.s., only 16 inches. The distances are still further diminished by effects of surface waves, air bubbles and bending of the beam due to varying temperatures.

Thus to get maximum range it is evidently desirable to use a low frequency. On the other hand, when the frequency is low the crystal must have a large diameter if the cone-shaped beam of sound is to be sufficiently narrow to locate a target accurately and to produce a strong echo. As a compromise it has been found most practicable to give the crystal a diameter of about 10 inches, in which case a cone of suitable divergence is produced when the frequency is around 40,000 c.p.s. For short ranges smaller crystals and higher frequencies can be used

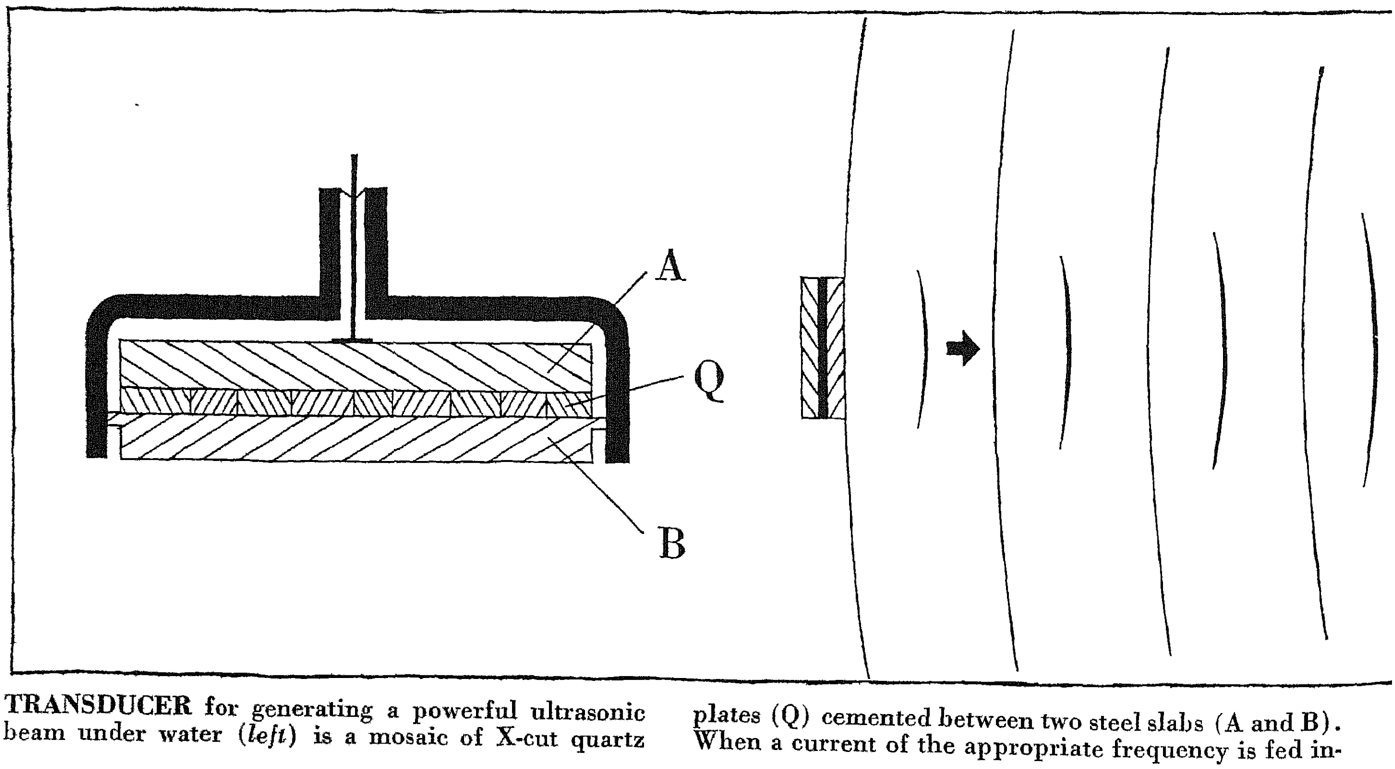
The device that transmits such a beam and receives its echo is known as a transducer. Its operation is illustrated in the drawing on these two pages. The transducer sends out a short pulse of ultrasonic waves. It is then immediately switched from the transmitting to the receiving circuit, so as to be ready to respond to the echo. A response can be detected even when the amplitude of motion is less than a hundredth of the diameter of a molecule.

MODERN transducers are of many sizes, shapes and designs. The present account is confined to transducers employing piezoelectric crystals, although some widely used types are magnetic rather than piezoelectric; they are based on the effect known as magnetostriction.

We will consider first the recent development of crystal transducers for sonar, which term, by the way, is derived from "Sound Navigation and Ranging." Sonar is the name for all devices for obtaining echoes from submerged objects, reefs, shores and the ocean bottom. Such devices can be used not only to detect submarines but to sound the depth of water in oceans and harbors and to locate sunken ships. They may also prove useful for locating icebergs in foggy weather or at night, although this is a more difficult problem than it may seem, for the reflection of sound under water from a mass of ice is very feeble.

Owing partly to the scarcity of quartz, and partly to the desire for a more strongly piezoelectric material, efforts were made as early as World War I to replace quartz by artificial crystals. For many years the only available substitute for quartz was Rochelle salt Later it was found that crystals of ADP, though less strongly piezoelectric than Rochelle salt, offered pronounced advantages, and they are now in common use.

In a typical transducer each crystal plate may be an inch square and a sixteenth to a quarter of an inch thick, with metal electrodes covering its opposite faces. A large number of these plates are stood on end on a flat surface, with suitable spacers between plates and between rows of plates. When cemented together they form a flat slab, the area of which may be a square foot or more. The electrodes are connected in parallel, or in a series-parallel combination, with terminal wires running to the high-frequency alternating-current generator. When a current of the right frequency is applied, the entire slab becomes alternately thicker and thinner; that is, it resonates in thickness vibration. The slab is mounted in a water-tight casing, with a "diaphragm" or "window" which allows the vibrations to pass through, for radiating



TRANSDUCER for generating a powerful ultrasonic beam under water (*left*) is a mosaic of X-cut quartz plates (Q) cemented between two steel slabs (A and B). When a current of the appropriate frequency is fed in-

and receiving ultrasonic waves under water.

In one of the most modern types of transducer the crystals are between steel slabs, forming a sandwich. The thinner crystals are at the center. Since their electrodes are closer together than those of the thicker crystals, their electric fields are stronger and they vibrate with greater amplitude. It is found that by this means the cone of radiation is more concentrated. The right and left halves of the transducer are connected to independent circuits. If the transducer is not pointing exactly at the target, there is a slight difference in time of arrival of the echo waves on the two halves. This difference is indicated on the screen of an oscilloscope, thereby enabling the operator to train the transducer more accurately on the target. The same transducer can be used also for detecting sounds of independent origin, such as the noises from distant propellers.

The transducers described thus far have flat faces for emitting a more or less narrow cone of sound. For special purposes it is sometimes desirable to send or receive in all directions. By a suitable arrangement of crystals this also can be accomplished.

TRANSDUCERS for producing ultrasonic waves have other uses than for underwater signaling. One example is a device for detecting flaws in metal castings and other solid materials. A quartz plate in a special holder is placed in contact with the specimen to be tested. A short pulse of high-frequency waves is sent into the specimen. Any air bubble, crack or other defect that lies in the path of this ultrasonic beam returns an echo to the crystal and is recorded electrically.

Transducers are also used in the storage or "memory" cells of certain radar systems and some electrical computing machines (SCIENTIFIC AMERICAN, April). The signal to be stored modulates a short pulse of high-frequency current, which in turn excites vibrations in a crystal transducer. The latter sends the modulated waves through a tube filled with mercury, at the opposite end of which is a second crystal. This second crystal reconverts the ultrasonic waves into an electric current, which is fed back into the circuit at the end of a storage interval that is determined by the length of the column of mercury.

How closely the transducer parallels radar is illustrated by the fact that it is actually used as a substitute for a radar set in training operators. When airborne radar was being developed the need was felt for a ground-training device by which radar operators could obtain experience in the novel and complicated procedure of handling the controls and adjusting images on the oscilloscope without actually going up in a plane. This end was achieved by an ultrasonic device called the "radar trainer," originated in England and further developed at the Massachusetts Institute of Technology Radiation Laboratory. In this apparatus the radar antenna is simulated by a small quartz transducer, which generates short ultrasonic pulses in a tank of water a few feet long. The ultrasonic waves are reflected from a relief map on the bottom of the tank, just as radar echoes are reflected from the terrain to a plane flying above it. Since the speed of electric waves in the air is about 200,000 times as great as that of sound waves in water, the time of flight of a pulse in the tank is of the same order of magnitude as that of a radar pulse in the round trip to a distant target and back. The ultrasonic beam scans the relief map exactly as a radar beam from a plane scans objects on the ground.

Many laboratory investigations have been carried out on the mechanical, chemical and biological effects of intense ultrasonic radiation. Some of these effects are spectacular. For example, a strong ultrasonic beam directed upward in a tank of water will make a jet of liquid or a cloud of mist shoot upward a foot or more from the surface. Though the amplitude of motion in the beam (*i.e.*, the distance the particles travel) is tiny, the forces of compression and rarefaction generate a pressure of several atmospheres. Moreover, because of the high frequency the velocities and accelerations of the particles in the medium are extremely large. The result is that the material in the path of the beam is so violently agitated that it tends to be torn apart.

This powerful agent called ultrasonics has opened new avenues to progress in many industries. Among the applications are the preparation of emulsions; giving a finer grain to metals and photographic films; freeing liquids from dissolved gases, the purification of milk. Ultrasonic waves of suitable frequencies and intensities can speed up chemical reactions, stimulate the germination of seeds and kill bacteria.

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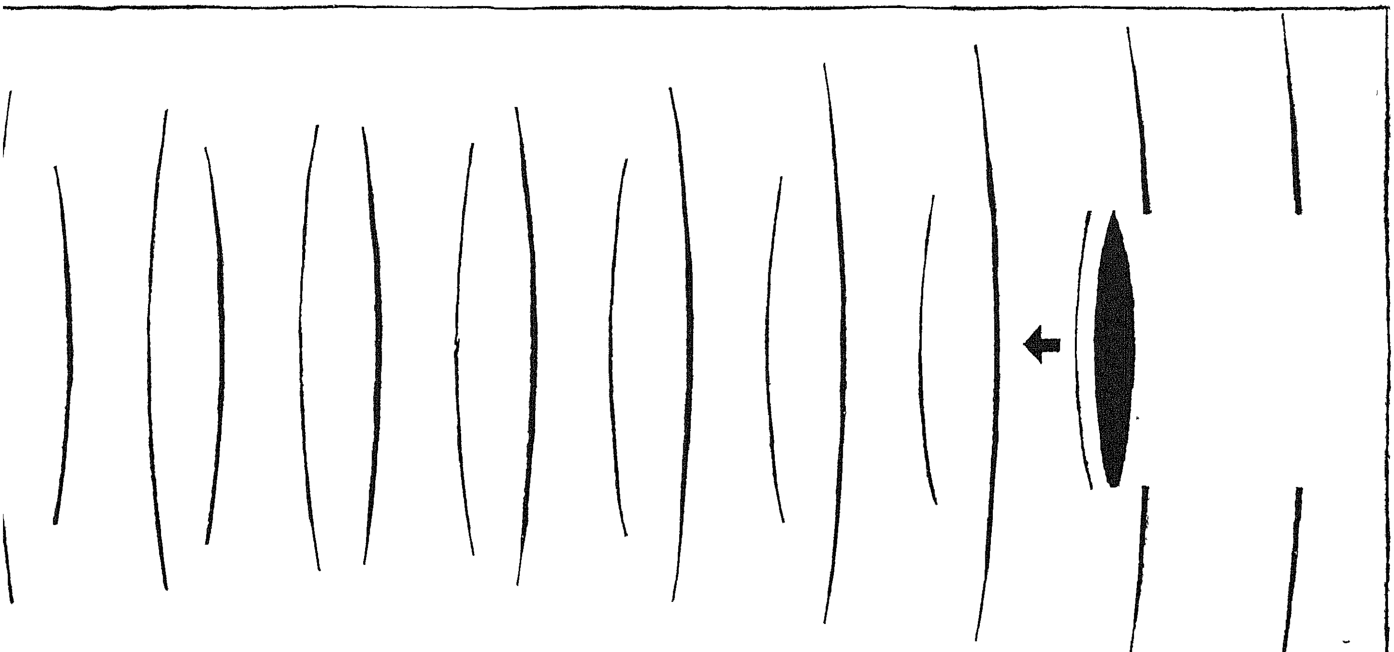
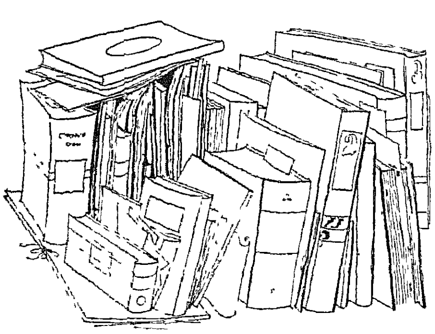


to the crystal, slab B sends acoustic waves into the water. To the right is a drawing of the transducer's application in submarine detection. Ultrasonic waves generated by transducer are reflected by submarine's hull.



CHILDREN'S BOOKS

A special review of those about science for groping parents at Christmastime

by James R. Newman

DURING the summer and fall I spent a good many hours going through some 300 children's science books. My purpose was to combine the duties of parent and book reviewer to make a moderately comprehensive survey of what was currently available and to share what I had learned with my children and with other children's parents, especially those who are readers of this magazine. The detailed conclusions on about a third of the total are to be found below, but a few general observations may be appropriate as an introduction.

First, it is evident that the art of writing simple, explanatory science texts for children has advanced considerably during the last half-century. My library holds a number of children's science books, written between 1900 and 1920, which I can recommend to neither children nor adults. The style is sentimental, the whimsy terrifying, the illustrations apparently prepared with a leaking pen, the type and binding repellent. There are exceptions, of course, especially among the books intended for older children. You will not find anything by contemporary authors to match the old masters: Michael Faraday on the candle, T. H. Huxley on a piece of chalk, John Tyndall on sound, Sylvanus Thompson on magnetism, C. V. Boys on soap bubbles. But for all their elegance and clarity, many such essays are not easy reading; to say they are accessible to adolescents is perhaps only to say that in intellectual grasp the average 15-year-old is the peer of the average adult and that he makes up in curiosity and receptiveness to new ideas what he may lack in information. A science primer, I have come to realize, should possess the attributes of a well-designed puzzle. It should be hard to master but not too hard, for in that case it will be rejected before it awakens the imagination necessary to solve it.

Looking over some of the British elementary science books by James Jeans, William Bragg, E. N. da C. Andrade, J. P. Kendall and others, based on lectures delivered in the notable Royal Institution Christmas Lecture Series, one is struck by the same point. We have almost nothing to equal these popularizations, as we have almost nothing (the Philadelphia Franklin Institute Lectures are a possible exception) to equal the Christmas lectures. But it is a mistake to assume that, because the Royal Institution Series is described as directed to a "juvenile auditory," the books themselves can be read by any but exceptionally gifted children. I think the science books published in the U. S. for the vague "12 and up" group are on the whole better suited for the average child, they are more cognizant of his limitations and more deliberately aimed at overcoming them. Although written with less imagination and less depth, they are superior in their broad appeal to many children without special scientific aptitude who, nevertheless, are interested in science and whose interest should be fulfilled I need waste no time, I am sure, on commonplaces about the importance of science in modern education.

Second, the bulk of current science books for younger children (6 to 9, 9 to 12) are remarkably satisfactory. My own early experience with science books began, to the best of my recollection, with the nature stories of Thornton W. Burgess. I was pleased with these, and I do not now intend to slight my obligation to them. The fact remains that my children regard Burgess as an old fogy. Undoubtedly some youngsters still enjoy reading about animals that go lippety-lip, moreover, these children should have no difficulty picking up perfectly sound information about nature. Others, however, now prefer taking science straight, and it is good, I think, that most modern primers give it straight.

One is impressed most of all by the range of beginners' texts. Besides the usual books about birds, mammals, insects, stars, snakes, flowers and fish, there are available for children under 12 suitable primers on embryology, weather, weights and measures, physiology, physics, chemistry, anthropology, geography, manufacturing, railroads, machinery, carpentry, cooking, geology and other estimable subjects.

Another clear gain resulting from modern educational theory is the advance in visual teaching, reflected in the many colorful, ingenious illustrations to be found in the better children's books. When text and illustrations are successfully combined, there is almost no limit to the subject matter that can be effectively introduced at the younger level.

The selections below are a fairly representative but in no sense a complete collection of the last few years' crop. Not a few good books were omitted because of space limitations, others were not available, and some, no doubt, are unknown to me. Many books are included because they are current, not because they are good, some of older vintage are briefly referred to because they are recent reprints of popular favorites

Physical Sciences

WHAT MAKES THE WHEELS GO ROUND, by Edward G. Huey. Reynal and Hitchcock, 1940 ($2.50).

UNDERSTANDING SCIENCE, by William H. Crouse. Whittlesey House, 1948 ($2.75).

MODERN WONDERS AND HOW THEY WORK, by Captain Burr W. Leyson. E. P Dutton and Co., 1949 ($3.50).

THE SKY IS BLUE, by W. Maxwell Reed. Harcourt, Brace and Company, 1932 ($2.00).

AND THAT'S WHY, by W. Maxwell Reed. Harcourt, Brace and Company, 1932 ($1.75).

I'LL SHOW YOU HOW IT HAPPENS and IF YOU COULD SEE INSIDE. Both by Marie Neurath. Chanticleer Press, Inc., 1949 ($1.50 each).

YOU AND ATOMIC ENERGY, by John Lewellen. Children's Press, Inc., 1949 ($1.50).

PICTURE BOOK OF MOLECULES AND ATOMS, by Jerome S. Meyer Lothrop, Lee and Shepard Co., Inc., 1947 ($2.00).

THE STORY OF SOUND, by James Geralton. Harcourt, Brace and Company, 1948 ($2.00).

THE BRIGHT DESIGN, by Katherine B. Shippen. The Viking Press, 1949 ($3.50).

ELECTRONICS FOR YOUNG PEOPLE, by Jeanne Bendick. Whittlesey House, 1947 ($2.00).

HOW BIG IS BIG?, by Herman and Nina Schneider William R. Scott, Inc, 1946 ($1.50).

The reason for listing Mr. Huey's book (for children of 10 and up), although it was published almost 10 years ago, is that nothing comparable has come along in the interval. It explains heat, light, electricity, magnetism, sound, inertia and friction, and such familiar objects as radios, telephones, locomotives, automobiles, steam shovels, vacuum cleaners, ice cream cones, airplanes and rubber boots. There are effective illustrations and an index. For either classroom or

home it sets a standard by which to measure successors. Mr. Crouse undertakes a similar task for high-school readers. Here, of course, there is more competition, including a number of acceptable school texts. Besides the usual topics, Crouse describes the operation of transformers, rocket and jet engines, radar, the atomic bomb and other modern devices. The book is notable for unencumbered writing and illustrations by Jeanne Bendick up to her customary quality. Captain Leyson's "modern wonders" will give your high-school son a pretty narrow view of what science is about. bombs, rockets, military jets, supersonic speed ("its dire potentialities"), guided missiles, robots, radar, proximity fuze, space ships ("military value . . . dire possibilities"), and so on.

The two Reed books (8 to 12) are not to be compared with his Science-for-Sam series, reviewed below. In each case a no better than passable text and wholly inadequate illustrations make a dull package. Miss Neurath's little primers (7 to 10) are completely gay and charming. Printed and designed in England, these volumes embody all that is desirable in the genre of brief, elementary science stories. *I'll Show You How It Happens* tells how fire makes an engine go, how shadows fall, how coal is made, how the turning of the earth makes day and night. The other volume presents beautifully simple, cross-sectional drawings of such objects as a house, a lighthouse, a ship, a volcano, a pyramid and a wasp's nest. It is a pity the books are so high-priced.

The Schneiders' altogether admirable little volume answers the many questions children (7 to 10) ask about size. By means of a number of comparisons (elephants with trees with skyscrapers with mountains with the moon, earth and stars) children learn how small they and their parents really are in relation to certain other objects in the physical world. Then by reversing the scale (from man to dog to mouse to flea to a drop of water to algae and finally to atoms) they are enabled to gain full perspective and appreciate their true place in the hierarchy of size—midway, roughly speaking, between the smallest and the largest of things. A delightful book.

From Jerome Meyer's picture book children (8 to 12) can learn about molecular structure, neutrons, protons, the behavior of gases, fission, chain reactions and, to be sure, the atomic bomb (how could children get on without it). Not exceptional, but satisfactory. Despite the formidable advisory services of Glenn T. Seaborg, co-discoverer of plutonium, Mr. Lewellen's book on atomic energy misses fire. The illustrations do not quite fill the gaps in a text which is likely to leave 10-year-olds with a fresh set of confusions in place of ignorance.

Mr. Geralton, a Harvard physics instructor, writes literately for children of 10 to 14 about pitch, frequency, resonance and other concepts of the science of sound; the illustrations are lively and graceful. This is still not a wholly satisfactory physics primer, mainly because neither text nor pictures are sufficiently analytic. Complex things are not taken apart so that the relationship between their elements can be understood.

By means of a series of brief, anecdotal biographies, Miss Shippen describes (for 12-year-olds and older) the evolution of electromagnetic theory. Somewhat superficial on the theoretical side, but skillfully planned, well written and unusually successful in conveying an impression of the grand design of modern physics. Inadequately illustrated and overpriced.

The Bendick book is a revised reissue of *Electronics for Boys and Girls* An efficient, readable introduction, with praise due the small sketches, which are particularly helpful.

Picture Book of Astronomy, by Jerome S. Meyer. Lothrop, Lee and Shepard Co., Inc., 1945 ($2.00).

Introducing the Constellations, by Robert H. Baker. The Viking Press, 1942 ($2.50).

When the Stars Come Out, by Robert H. Baker. The Viking Press, 1944 ($2.50).

The Stars for Sam, by W. Maxwell Reed. Harcourt, Brace and Company, 1931 ($3.75).

Sun, Moon and Stars, by William T. Skilling and Robert S. Richardson. Whittlesey House, 1946 ($2.75).

The Stars in Our Heaven, by Peter Lum. Pantheon Books, Inc., 1948 ($3.75).

The Stars for Children, by Gaylord Johnson. The Macmillan Company, 1949 ($2.00).

The Book of Stars for Young People, by William Tyler Olcott. G. P. Putnam's Sons, 1923 ($3.75).

This group is fairly representative of the many available introductions to astronomy suited to every age level. It exhibits, also, the changes which have taken place in the last 25 years in educational method and attitude. Mr. Meyer is an old hand at juvenile science and novelty books. His picture book (6 to 10) is simply written and pleasantly illustrated. One would wish to see something better for this age group but this work will do until then.

Dr. Baker's two books (high-school level or even above if you don't mind a touch of condescension) are readable, well-designed and well-illustrated introductions, deserving of their popularity. The scientific and historical materials are skillfully blended into a flowing narrative which is at once informative and entertaining. One recalls, in this connection, that professional astronomers predominate among the noted popularizers of science.

Skilling and Richardson, aiming at a bright junior high-school and high-school audience, have produced an unassuming, highly palatable textbook, no disparagement being intended in the use of that term. The explanations are successful, there are helpful illustrations and suggestions for experiments, and the relation between astronomy and other sciences receives proper attention.

The Stars for Sam (any Sam over 12) is, in most respects, the outstanding book of its class. First-rate typography, over 100 photographs, diagrams and line drawings, a clear, well-paced text (with only minor inaccuracies) make a really exciting book which no child even faintly susceptible to astronomy ought to miss. One annoyance is that there is no index. As a supplement to any of the foregoing books designed for the upper age groups, Lum's collection of myths and fables about the stars, drawn from Roman, Greek, Chinese, Babylonian, Norse and Indian sources, is highly appropriate. A scholarly and solid volume; fascinating in not-too-large doses.

While Johnson and Olcott are both somewhat dated, in approach if not in information, they have merit and are not without charm. Olcott stresses the fables and the observational side of astronomy; Johnson has an inquiring Paul and Betty and a tireless, encyclopedic Uncle Henry who composes poetry, knows Latin, Greek, mythology and all about Cassiopeia, Aquila and Delphinus. Perfectly harmless.

The Land Renewed, by William R. Van Dersal and Edward H. Graham. Oxford University Press, 1946 ($2.00).

Minerals, by Herbert S. Zim and Elizabeth K. Cooper. Harcourt, Brace and Company, 1943 ($3.00).

The Earth for Sam, by W. Maxwell Reed. Harcourt, Brace and Company, 1930 ($3.75).

Stories in Rocks, by Henry Lionel Williams. Henry Holt and Company, 1948 ($3.00).

A highly satisfactory collection of books about the earth sciences. The Van Dersal-Graham book, with the help of a large number of admirable photographs, tells the story of soil conservation: how water, wind, greed and neglect have wasted the soil and what can be done about it. An important and readable essay, suitable for teen-agers as well as adults.

Minerals has the qualities usually found in the writings of the prolific Mr. Zim. It is honest, direct, accurate and supported by apt illustrations. Recommended for the amateur collector of almost any inert object to be found on the ground. Mr. Williams presents for the junior high-school age group a balanced introduction to historical geology, somewhat less exciting than Reed's popular book but also less whimsical. Each of these volumes has its own attractive features. Mr. Reed's is noted for the remarkable range of its illustrations,

though with successive printings the reproductions regrettably grow shabbier.

Biological Sciences

FROM HEAD TO FOOT, by Alex Novikoff. International Publishers, 1946 ($2.00).
HOW MAN DISCOVERED HIS BODY, by Sarah H. Riedman. International Publishers, 1947 ($2.25).
CLIMBING OUR FAMILY TREE, by Alex Novikoff. International Publishers, 1945 ($2.00).
EGG TO CHICK, by Millicent E. Selsam. International Publishers, 1946 ($1.00).

A superior assortment out of the Young World Book series. Dr. Novikoff's account of our bodies and how they work (12 and up) is filled with sound historical and scientific information, freshly and interestingly told. For a beginning physiology it is remarkably comprehensive: circulation, blood corpuscles, digestion, nervous system, hormones, reproduction, genetics, metabolism and so on. Helpful pictures A history of physiology is the main theme of Dr. Riedman's story (12 and up), which runs from Harvey to Pavlov, and takes note, along the way, of the general development of scientific method and particularly of the relation between the progress of physiology and advances in other sciences. *Climbing Our Family Tree* (12 and up) is an excellent introduction to evolution

The Selsam book (6 to 9) is nothing less than a *tour de force*. In 28 pages it recounts the changes that take place inside an egg from the time it is laid until the bedraggled chick cracks its way out and becomes, within a few hours, fully adept at managing its own life.

A BABY IS BORN, by Milton I. Levine and Jean H. Seligmann. Simon and Schuster, Inc., 1949 ($1.50).

Intended to serve younger children (6 to 10) who can read or be read to, as the authors' well-known *The Wonder of Life* has served older children Sexual function, reproduction, birth and the baby's first months honestly and unsentimentally portrayed. Recommended.

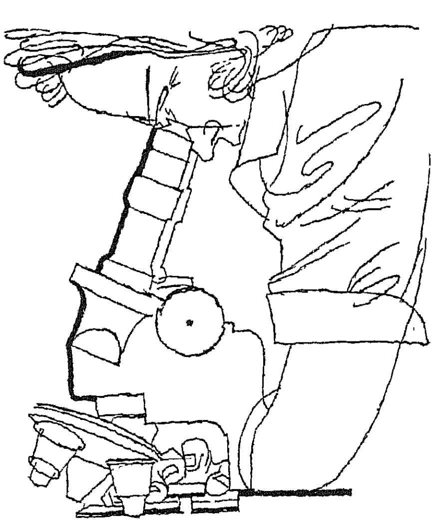
THE AMATEUR NATURALIST'S HANDBOOK, by Vinson Brown. Little, Brown and Company, 1948 ($3.50).

Just what the title says and very good too. A small, fat volume packed with facts and profusely illustrated. For any lover or collector of plants, animals, rocks and minerals. A thorough index and bibliography.

LET'S GO OUTDOORS, LET'S GO TO THE SEASHORE and LET'S GO TO THE DESERT. All by Harriet E. Huntington. Doubleday and Company, Inc., 1939 to 1949 ($2.50 each).

Superb photographs and simple text make these among the outstanding nature books for children up to 9. Nothing better in the entire field.

THE BURGESS BIRD BOOK FOR CHILDREN, by Thornton W. Burgess. Little, Brown and Company, 1919 and 1948 ($3.00).
TRAVELING WITH THE BIRDS, by Rudyerd Boulton. M. A. Donohue and Co., 1933 ($2.00).
BIRDS AT HOME, by Marguerite Henry. M. A. Donohue and Co., 1942 ($2.00).
A CHILD'S BOOK OF BIRDS, by Luis M. Henderson. Maxton Publishers Incorporated, 1946 (50 cents).
LISTEN TO THE MOCKINGBIRD, by Irmengarde Eberle. Whittlesey House, 1949 ($2 00).
STARLINGS, by Wilfrid S. Bronson. Harcourt, Brace and Company, 1949 ($2.00).
HOMING PIGEONS, by Herbert S. Zim. William Morrow and Company, 1949 ($2.00)



RUFOUS REDTAIL, by Helen Garrett. The Viking Press, 1947 ($2 50).
BIRDS: A GUIDE TO THE MOST FAMILIAR AMERICAN BIRDS, by Herbert S. Zim and Ira N. Gabrielson. Simon and Schuster, Inc., 1949 ($1.00).

Selected from an immense crop of books about birds, these are representative of the better efforts. Burgess (8 and up) is fine for children who like Burgess, Boulton and Henry are large-print picture books, well colored; Henderson is very nicely and unassumingly done for younger children. The next few volumes are specialties, each of which will appeal either as nature study cast in fiction form or, as in the case of Zim and Bronson, as introductory manuals of birdlore about particular species. (Eberle 8 to 12; Bronson 7 up, Zim 12 to 16, Garrett 8 or 9 up). *Birds,* a Golden Nature Guide, is a find. Real pocket size; clear, accurate text; 112 color plates; packed with information about the traits and habits of the most common birds of America. Everything about this delightful book, including the price, merits praise for the illustrator, authors and publishers. Indispensable for bird watchers or anyone who ever looks out of his window.

THE INSECT WORLD, by Hilda T. Harpster The Viking Press, 1948 ($3.00).
THE GRASSHOPPER BOOK, by Wilfrid S Bronson. Harcourt, Brace and Company, 1943 ($2.25).
INSECT ODDITIES, by Raymond Ditmars. J. B. Lippincott Company, 1938 ($2.25).

Each of these books is informative, accurate and interesting Harpster (12 up) is general, telling about insect diet, habits, homes, armor, camouflage and the like; Bronson (8 up) and Ditmars (7 up) are studded with the kind of details children and adults never tire of.

THE SEA FOR SAM, by William M. Reed. Harcourt, Brace and Company, 1935 ($3.75).
THE BURGESS SEASHORE BOOK FOR CHILDREN, by Thornton W. Burgess. Little, Brown and Company, 1929 and 1948 ($3.00).
THE GULF STREAM, by Ruth Brindze. The Vanguard Press, 1945 ($2.50).
GOLDFISH, by Herbert S. Zim. William Morrow and Company, 1947 ($2.00).

A good lot. Reed (10 to 11 and up) and Burgess (8 up) are, of course, standard, differing in approach but both liked by children. Reed, however, takes in addition to marine life the sciences of waves, tides and currents. *The Gulf Stream* (9 to 12) is history and science: an unusual story handsomely illustrated. Highly recommended Zim's book not only tells a 7- or 8-year-old everything he would ever want to know about goldfish but gives clear advice on how to build and maintain an aquarium

THE BURGESS ANIMAL BOOK FOR CHILDREN, by Thornton W. Burgess. Little, Brown and Company, 1920 and 1948 ($3 00).
FARM ANIMALS, by Dorothy Childs Hogner. Oxford University Press, 1945 ($3.50).
THE ANIMAL BOOK, by Dorothy Childs Hogner and Nils Hogner Oxford University Press, 1942 ($3.50).
FRIENDLY ANIMALS, by Karl Patterson Schmidt. M. A. Donohue and Co., 1947 ($2.00).
WILDLIFE FOR AMERICA, by Edward H. Graham and William R. Van Dersal. Oxford University Press, 1949 ($2.50).
ANIMAL TRACKS, ANIMAL HOMES and ANIMAL SOUNDS All by George F. Mason. William Morrow and Company, 1943 to 1948 ($2.00 each).
HORNS AND ANTLERS, by Wilfrid S. Bronson. Harcourt, Brace and Company, 1942 ($2.50).
COYOTES, by Wilfrid S. Bronson. Harcourt, Brace and Company, 1946 ($1.75).
MICE, MEN AND ELEPHANTS, by Herbert

S. Zim. Harcourt, Brace and Company, 1942 ($2.00).

RABBITS, by Herbert S. Zim. William Morrow and Company, 1948 ($2.00).

The older favorites hold their place; Burgess, with only fair color plates, is instructive and simple; the Hogner volumes (12 to 16), *The Animal Book* in particular, are thorough, wide in scope and as handsome as anything to be found on library shelves. They cannot be recommended too highly. *Friendly Animals*, by the Curator of the Chicago Natural History Museum, will do for younger children. The material is quite limited in comparison with the content of Burgess or Hogner. Graham and Van Dersal have extended their conservation story from soil (*see Physical Sciences*) to wildlife. Striking photographs accompany a well-organized, convincing text.

For 8-year-olds and up who enjoy nature study the Mason books offer much that is useful as well as intriguing. They describe how animals live and build their homes, the kind of footprints and other tracks they leave in mud or snow, their night noises, chirps, warning signals, songs and bellows. Even an alligator will respond, says Mr. Mason, who is a scientist and artist on the staff of the American Museum of Natural History, to the sounding of B flat on a French horn or 'cello. Mr. Bronson's writings (6 to 10) are usually amusing, pleasantly illustrated and accurate. His genuine feeling for animals carries over in these, just as in his many other books. If your child likes and/or keeps (or threatens to keep) rabbits, Mr. Zim's book on the subject is a necessity. It will help preserve the rabbits as well as your peace of mind. *Mice, Men and Elephants*, while offering no advice on the maintenance of a backyard elephant hutch, is an able account of the physiology of mammals in general. Photographs and text tell about porcupines, cats' whiskers, mammary glands, the heart (it beats 39,420,000 times a year, excluding tense interludes), the brain, temperature controls, mating, sea elephants, and male skunks—who refuse to help in raising their families. Recommended, especially to help parents through the question period.

THE BURGESS FLOWER BOOK FOR CHILDREN, by Thornton W. Burgess. Little, Brown and Company, 1923 and 1947 ($3.00).

FRUITS OF THE EARTH and INDIAN HARVEST. Both by Jannette Lucas and Helene Carter. J. B. Lippincott Company, 1942 and 1945 ($2.00 each).

LET'S LEARN THE FLOWERS and LEAF, FRUIT AND FLOWER. Both by Marshall McClintock. Chanticleer Press, Inc., 1948 ($1.00 each).

ANYWHERE IN THE WORLD, BITS THAT GROW BIG and UP ABOVE AND DOWN BELOW. All by Irma E. Webber. William R. Scott, Inc., 1947 ($1.50 each).

CHILD'S GARDEN OF FLOWERS and CHILD'S GARDEN OF VEGETABLES. Both by Robert V. Masters. Greenberg: Publisher, 1949 ($1.00 each).

BIG TREE, by Mary and Conrad Buff, The Viking Press, 1946 ($3.00).

Burgess has 113 illustrations in black and white, muddy color reproductions and the usual assortment of Peter Rabbit, Merry Little Breeze, Bubbling Bob, Blue-Eyed Grass, Buster Bear, Mr. Grouse and others. Nothing can be done about it, the facts are accurate and young children are perhaps less sensitive than the reviewer. For children of 10 and up the Lucas-Carter books are just right, forthright and attractive. Chanticleer Press deserves success in the 6-to-10 market; their photography books are lively, with large type and satisfactory color reproductions. The prices are sensible. Dr. Webber's books (7 to 11) are carefully thought out. Her illustrations match a lucid text which by a fresh approach conveys ideas usually thought to be above this age group. *Bits That Grow Big* includes easy but valuable experiments. Along this line the two Masters books (8 up) can also be recommended. Each contains five packages of Burpee seeds with explicit directions for indoor and outdoor planting and care. The books themselves are cheaply made, because here the seeds are the thing. Once the directions are followed the manual can be discarded.

Big Tree, the story of a Sequoia (10 to 15), is a beautiful book. It is a narrative simply told, elegant in illustration and design. Splendid for any child's library.

SNAKES ALIVE, by Clifford H. Pope. The Viking Press, 1946 ($3.50).

The best book of its kind. Everything that any amateur would want to know about snakes. their physiology, senses and intelligence, feeding habits, reproduction, locomotion, defenses, venoms and so on.

Social Sciences

ALL ABOUT US, by Eva Knox Evans. Capitol Publishing Co., 1947 ($2.00).

THIS IS THE WORLD, by Josephine Van Dolzen Pease. Rand McNally and Company, 1946 ($2.50).

LET'S READ ABOUT BRAZIL, by Stella Burke May. The Fideler Company, 1948 ($2.95).

LET'S READ ABOUT CHINA, by Cornelia Spencer. The Fideler Company, 1948 ($2.95).

MY FIRST GEOGRAPHY OF THE AMERICAS, by Arensa Sondergaard. Little, Brown and Company, 1946 ($1.75).

MY FIRST GEOGRAPHY OF THE PACIFIC, by Arensa Sondergaard. Little, Brown and Company, 1946 ($2.00).

SKY HIGHWAYS, by Trevor Lloyd. Houghton Mifflin Company, 1945 ($2.50).

For all its whimsy, which is probably no worse for your child than are Captain

Midnight and the like, *All About Us* is a civilized book based upon an excellent idea. Accessible to all but the youngest children, it tells how men are alike, how they differ and how secondary are the most obvious differences of race, color and creed. A weapon against misinformation and bigotry, this book should be required reading to precede a child's introduction to the Bill of Rights.

For preschool-age children, the Pease introduction to geography is among the best of its kind. The facts are intelligently selected and imparted with a simplicity which conceals a good deal of forethought and direction.

The next two volumes are conventional geographies (8 to 12) full of unobjectionable facts, with slightly better than average photographs. Part of a series on Australia, Brazil, Alaska, Russia, India, and so on.

Geography of the Americas has a minimum of words and an abundance of bright, charming sketches in full color. ships, bridges, trains, canals, machines, oil fields, forests, fruits, volcanoes, native costumes and maps. Perfect for 6-to-9-year-olds. Miss Sondergaard's book on the Pacific (8 to 12) is another treasure. The subject matter is fascinating, the narrative clear and fluent, the colored illustrations superb. Easily the most original and successful geography primer that has yet appeared.

Sky Highways (8 to 13) is a world survey from the air. You start in Washington, fly to Brazil, across Africa to India, then through Chungking, Siberia, Alaska, Canada and home. Really more about flying, weather and air routes than about what lies below Maps, diagrams, satisfactory writing.

Technology

THE CHEMICAL INDUSTRY, THE COAL INDUSTRY, THE COTTON INDUSTRY, THE ELECTRICAL INDUSTRY, FISH PRODUCTION, THE GLASS INDUSTRY, THE PAPER INDUSTRY, THE PLASTICS INDUSTRY, THE PETROLEUM INDUSTRY, THE RUBBER INDUSTRY and THE STEEL INDUSTRY. All by Josephine Perry. Longmans, Green and Co., 1940 to 1947 ($2.00 each).

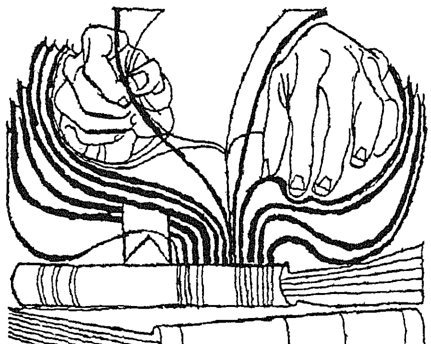
THE STEEL BOOK, THE GLASS BOOK and THE PAPER BOOK. All by William Clayton Pryor and Helen Sloman Pryor. Harcourt, Brace and Company, 1935 and 1936 ($1.50, $1.50 and $1.00).

ALUMINUM FROM MINE TO SKY, by June Metcalfe. Whittlesey House, 1947 ($2.50).

COPPER, by June Metcalfe. The Viking Press, 1946 ($2.50).

PLASTICS and RAYON, NYLON AND GLASS FIBERS. Both by the W.P.A. Pennsylvania Writers Project. Albert Whitman and Co., 1945 (75 cents each).

In the America at Work series Miss Perry attempts, for grade-school-age children, a brief description of the history and technical processes of a number of major industries. The idea is good. The execution, unfortunately, has the inspiration and tone of a stockholders' report. Miss Metcalfe's stories of aluminum and copper, on the other hand, are excellent. They recount the historical evolution of the two metals and give simple, well-illustrated accounts of the processes employed in mining, refining, metallurgy and manufacture. On a more elementary level, the Pryors in their photographic picture books convey a great deal of accurate, understandable information about the modern methods used in the production of paper, glass and [illegible] brief, inexpensive little handbook [illegible] signed for third- or fourth-grade [illegible] dren, the W.P.A. Pennsylvania Wr[illegible] Project science readers (there [illegible] more than those reviewed here, [illegible]



straightforward, satisfactory introductions. The type is large and there are illustrations.

Biography

YOUNG AUDUBON, by Miriam E. Mason. The Bobbs-Merrill Company, 1943 ($1.75).

ALECK BELL, by Mabel Cleland Widdemer. The Bobbs-Merrill Company, 1947 ($1.75).

GEORGE CARVER, by Augusta Stevenson The Bobbs-Merrill Company, 1944 ($1.75).

LUTHER BURBANK, by Olive W. Burt. The Bobbs-Merrill Company, 1948 ($1.75).

TOM EDISON, by Sue Guthridge. The Bobbs-Merrill Company, 1947 ($1.75).

ROBERT FULTON, by Marguerite Henry. The Bobbs-Merrill Company, 1945 ($1.75).

BEN FRANKLIN, by Augusta Stevenson. The Bobbs-Merrill Company, 1941 ($1.75).

These volumes in a well-known series about noted Americans in many different fields are 9-to-13-year-old-level biographies, mostly anecdotal, concerned with the subject's life through adolescence. The last chapter is usually a summary of his later achievements. They have a stereotyped, written-to-order flavor, but are reputed to be popular among parents.

AMERICAN INVENTORS and AMERICAN SCIENTISTS. Both by C. J. Hylander. The Macmillan Company, 1934 and 1935 ($2.50 each).

Collections of biographical notes about Bell, Morse, Fulton, Franklin, Ericsson, Remsen, Silliman, Newcomb, Agassiz, Millikan and many others. Frequently reprinted, these volumes, addressed to 12-to-16-year-old readers, are, I suppose, adequate of their sort: unassuming, accurate, sprinkled with entertaining details. The scientific explana-

[illegible]

and other visual aids could have been substituted to advantage.

HEROES OF CIVILIZATION, by Joseph Cottler and Haym Jaffe. Little, Brown and Company, 1931 and 1947 ($3.00).

An established favorite, consisting of brief sketches of explorers (from Marco Polo to Amundsen), scientists (Copernicus to Einstein), inventors (Gutenberg to the Wright brothers), biologists and doctors (Harvey to Mendel). A very good book for hero-worshippers.

THAT LIVELY MAN, BEN FRANKLIN, by Jeanette Eaton. William Morrow and Company, 1948 ($2.50).

An uncommonly attractive and balanced account of the life of this remarkable man. It is written without condescension, with color and spirit, describing equally well the man, the scientist, the philosopher and the practical statesman. Highly recommended for readers up to 13 or so.

Home Experimentation

FUN WITH SCIENCE and FUN WITH CHEMISTRY. Both by Mae and Ira Freeman. Random House, 1943 and 1944 ($1.50 each).

AFTER-DINNER SCIENCE, by Kenneth M. Swezey. Whittlesey House, 1948 ($3.00).

EXPERIMENTS IN SCIENCE and EXPERIMENTS WITH ELECTRICITY. Both by Nelson F. Beeler and Franklyn Branley. Thomas Y. Crowell Company, 1947 and 1949 ($2 50 each).

LET'S LOOK INSIDE YOUR HOUSE and LET'S FIND OUT. Both by Nina and Herman Schneider. William R. Scott, Inc., 1948 and 1949 ($1.50 each).

Some children are born experimenters and others are not. Even among the great scientists there have been those who were all thumbs in the laboratory. A good home-experiment manual must be based on a recognition of these wide differences in aptitudes and methods of

learning, providing exercises that children can perform whether or not they are naturally skillful. The experiments should be simple, the directions explicit, the materials and equipment available around the house, the results non-incendiary, non-destructive and non-lethal. The educational value of such books is almost self-evident, any interesting experiment will teach the experimenter more about the nature of science and how things work than the most lucid text.

Judged by these criteria the two Freeman books (10 to 14) are ideal. With ordinary tableware, nails, glasses, milk bottles, corks, marbles, paper, rubber bands, vinegar, baking soda, flashlight batteries and the like, the junior Galileo or Faraday can demonstrate the principles of inertia, the theory of heat, light, electricity and magnetism, molecular structure, the chemistry of combustion, the behavior of gases and so on. Directions and pictures are both first-rate. Beeler and Branley present somewhat more advanced experiments, especially in their book on electricity. Their program includes directions for making a bell, electromagnet, barometer, air cannon (quite safe), periscope, telephone, fire extinguisher and charcoal. Simple and satisfactory.

Mr. Swezey's book is supposed to amuse the family after dinner. Besides the usual harmless (and some pointless) experiments, it describes others requiring considerable care and skill. Sulfuric acid is not likely to improve one's clothing, manganese dioxide is not found in every grocery cabinet, zinc filings mixed with carbon tetrachloride over an open flame perched on the dining-room table will evoke no huzzas from mother. After dinner perhaps, but in a laboratory and under expert supervision.

The Schneider books (6 to 9) relate practical, easy experiments to familiar phenomena encountered in- and out-of-doors. The experiments are intended to answer such questions as why a teakettle sings, why cold water pipes sweat, where warm air goes, and how water flows uphill by itself. Straightforward, soundly organized and unassuming

Dictionaries and Encyclopedias

OXFORD JUNIOR ENCYCLOPAEDIA. VOLUME I, MANKIND, VOLUME III, THE UNIVERSE. Oxford University Press, 1949 ($10 00 each).

If the promise of these first two volumes (all that are thus far published) is maintained throughout the set it will be regarded as a notable addition to the juvenile reference shelf. The articles on the whole are excellent and the illustrations, if not strikingly original, are satisfactory. The *Oxford Junior Encyclopaedia* has been rather coolly received by some reviewers for the reason, among others, that it compares unfavorably with standard American junior encyclopedias. The comparison, however, is both unfair and inconclusive. The Oxford encyclopedia's approach and flavor are unmistakably British; its scholarship standards are high; it should be welcomed as a valuable companion to the best of its American counterparts.

Miscellaneous

CHILD'S BOOK OF CARPENTRY, by Jeanne Taylor. Greenberg: Publisher, 1948 ($2.50).

Anyone, child or adult, who wants to learn how to use nails, hammer and saw to better purpose than self-mutilation will be delighted with this book. Directions, for a change, are really easy to follow, the illustrations are admirable, there are instructions for making a boat, a bookcase, a footstool, a chest, a picture frame and a chair—everything according to the soundest practice.

THE BIG FIRE and RIDING THE RAILS. Both by Elizabeth Olds. Houghton Mifflin Company, 1945 and 1948 ($2.50 each).

Two brilliantly illustrated stories (7 to 12), the first a history of fire-fighting in a big city; the second, a history of railroads in the U. S. from Oliver Evans' Philadelphia Steam Wagon and Peter Cooper's Tom Thumb through the present-day steam, gas turbine, electric and Diesel locomotives. Distinguished children's books, enthusiastically recommended.

HOW MUCH AND HOW MANY, by Jeanne Bendick. Whittlesey House, 1947 ($2.25).

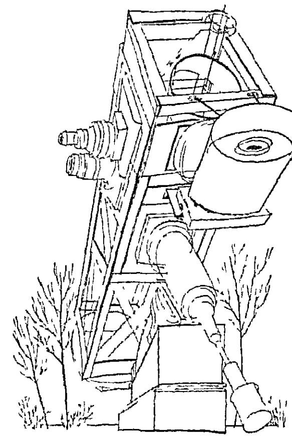
Facts about weights and measures: pounds, inches, carats, ems, meters, hours, watts, banks, drams, degrees of temperature, *f* stops in photography and so on. Simply told and effectively illustrated.

CODES AND SECRET WRITING, by Herbert S. Zim. William Morrow and Company, 1948 ($2.00).

Position codes, code wheels, breaking codes, secret writing, Pig Latin, invisible ink and similar jiggery-pokery Not, strictly speaking, a science book, but certain to interest youngsters with a bent for mathematics and a taste—hardly confined to young children—for the hocus-pocus of secrecy.

THE STORY OF OUR CALENDAR, by Ruth Brindze. The Vanguard Press, 1949 ($2.50).

Astronomy, cartography and horology are among the arts and sciences which enter these pages for their historic contribution to the making of the calendar. Miss Brindze answers such questions as why George Washington's birthday was changed, why we have leap year, how the calendar got its name. A fascinating story and a handsome book.



THE AMATEUR

Conducted by Albert G. Ingalls

CONSTRUCTION of the world's second largest telescope, 120 inches in diameter, will soon begin at the University of California's Lick Observatory on Mount Hamilton, 45 miles southeast of San Francisco, with the help of $1,800,000 from the State of California. When completed it will be second only to the California Institute of Technology's 200-inch some 400 miles to the south on Palomar Mountain.

The design of this great reflector has been under way for three years. A 120-inch, 8,500-pound ribbed Pyrex mirror blank has now been received and temporarily stored. The first thing to be built will be the observatory dome, since the mirror is to be ground, polished and figured within it, in a temporary optical shop located between the telescope foundation and the dome wall. This will make possible both horizontal and vertical testing of the mirror during polishing and figuring.

A staff of engineers under the direction of Senior Engineer Wilbert W. Baustian, formerly of Caltech, has carried out the design of the telescope. A massive 85-ton fork mounting will give access to the entire heavens at the latitude of Mount Hamilton The tube, similar in principle to that of the 200-inch, will be a welded structure of the open truss type, built of steel plate and tubing with square mid-section and round ends. It will, however, have much longer relative proportions than the 200-inch, the mirror having a focal ratio of $f/5$ instead of the Palomar telescope's $f/3.3$.

The 120-inch has been designed and is being built to profit from Caltech's experience with the 200-inch. The Pasadena institution has generously made these data completely available to the Lick workers. On the advice of the builders of the 200-inch, the plan until a year ago was to make the 120-inch mirror of 16-inch-thick solid glass. At that time the users of the 200-inch disk still regarded its ribbed construction as experimental. The 200-inch had to be ribbed because the transmission of heat through a disk is retarded in proportion to the square of its thickness. The necessary equalization of temperature throughout a solid 200-inch disk 24 inches thick would be an insoluble problem, for the temperature of the atmosphere is always changing and the disk's temperature would never catch up with it. With its ribbed construction the 200-inch mirror is only four inches thick in a temperature sense. It was held, however, that this kind of hindrance to temperature equalization would not be too critical in the 16-inch-thick solid disk recommended for the Lick telescope

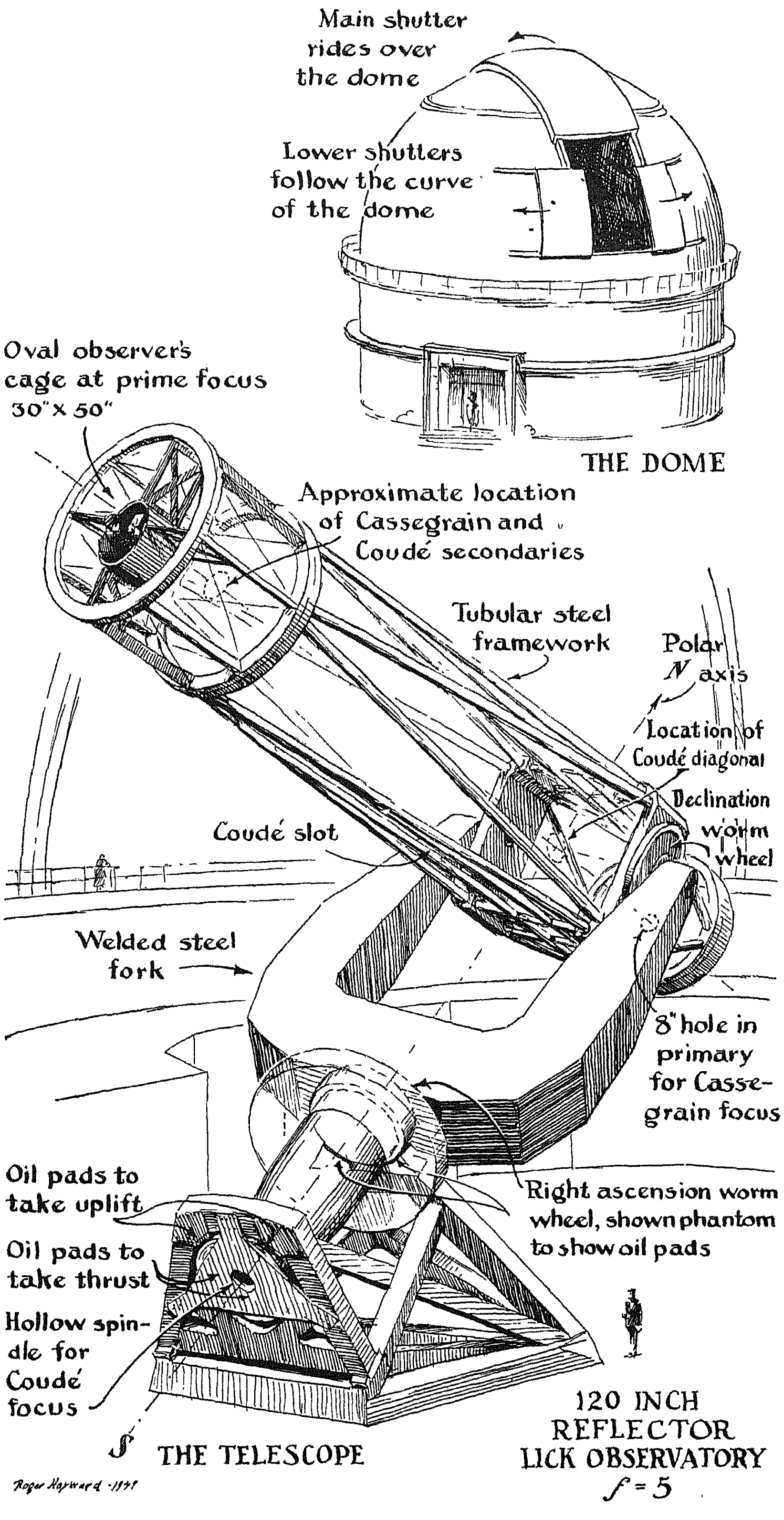
After the 200-inch ribbed mirror proved successful, however, the Lick designers bought the 120-inch ribbed Pyrex blank from the California Institute of Technology for $50,000. This blank, which has recently been delivered, was cast at Corning, N. Y., in 1933 for conversion into an optical flat for testing the 200-inch mirror. Other methods of testing were substituted, and the blank had stood unused in the optical shop at Pasadena for many years. Lick also bought the large grinding and polishing machine that was to have converted it into a flat.

The 120-inch blank is nearly perfect, remarkably homogeneous and uniform. On its front part, which is four inches thick, the curve of the new mirror will be excavated a maximum of 1½ inches. The disk will then be perforated with a hole eight inches in diameter to afford passage of light rays from the secondary mirror back to the Cassegrainian focus.

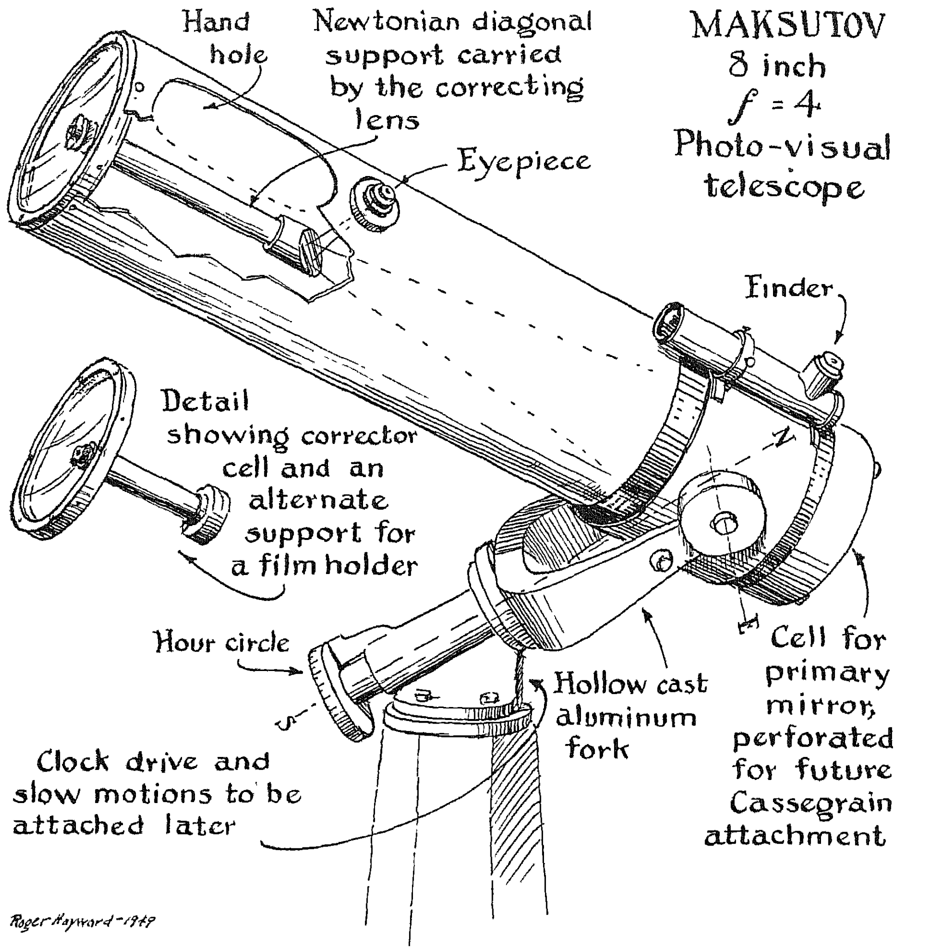
Difficulties that have long delayed the final completion of the 200-inch mirror were caused mainly by the fact that at no time during polishing and figuring could it be tested in the same generally horizontal position in which it is used in the telescope. For testing, it always had to be turned on edge. An irregularity in curvature—a high edge zone—was purposely not removed before the mirror was placed in the telescope, because theory indicated that when it was in horizontal position the bulge would sag out. When the mirror was placed in the telescope this theory proved erroneous. Yet testing the 200-inch mirror in a horizontal position would have required the temporary construction above it of a 125-foot tower, with insulation to prevent a change of temperature in the optical shop beneath it. At Lick the "tower" will be the 94-foot-high observatory dome itself, and this is why the dome must be built before work is begun on the mirror and mounting. Finishing the mirror within the dome will also permit its easy insertion in the mounting as often as required during that process.

Perhaps the most arresting feature of the 120-inch telescope, as drawn from

ASTRONOMER



The new 120-inch reflecting telescope for Lick Observatory



Broadhead's Maksutov telescope

the original designs by Roger Hayward (himself an amateur telescope maker), is the huge and stocky fork with its angular outlines. This was explained by the late Russell W. Porter "The fork form, which disturbs me, is due to the fact that it was impossible to compute the stresses if curved lines were used; it had to be computed with straight sections."

The Lick project will require about four or five years for completion after actual construction is begun. Although the telescope is not the largest, it has at least as much claim to interest among telescope makers and users as the 200-inch telescope. The 120-inch probably will permit exploration of the universe to a distance of 900 million light-years, and there is more than enough research to be done inside that limit of distance.

IN 1944 the Russian, Maksutov, announced in the *Journal of the Optical Society of America* his invention and patenting of a photographic and visual type of telescope that has become known as the "Maksutov," more familiarly the "Mak." Of the existing types of highly corrected photographic telescopes, the Mak most closely resembles the Schmidt. It has a spherical primary mirror at the bottom of its tube and a correcting lens at the top; but the correcting lens, unlike that of the Schmidt, is thick and deeply concave. In his detailed 15-page article Maksutov described its principle and suggested several interesting variations on its central theme—the Herschelian Mak, the Cassegrainian Mak, the Gregorian Mak, the brachyte Mak, and others

Norbert J. Schell of Beaver Falls, Pa., studied the Maksutov article, selected the simplest type—the Newtonian Mak—and at this magazine's invitation wrote articles, published in October and December, 1944, in which he gave all the design data necessary for making a Newtonian Mak. At the same time this department organized a buyers' club of advanced amateurs to reduce the cost of molding and casting the thick blanks of glass necessary for making the meniscus correcting lens (concavity ⅝-inch deep) at the skyward end of the Mak. The Corning Glass Works built a temporary mold and made 24 of these special blanks of crown glass having a refractive index 1.517 and a dispersion 64.5, each 8.2 inches in diameter and 1¼ inches thick. Then the mold was broken up and all the blanks were sold.

So far as is known only two Maksutovs were completed among this group. In 1945 Arthur DeVany of Des Moines, Iowa, made one for a comet seeker. In October, 1947, G. Camilli of Pittsfield, Mass., described in SCIENTIFIC AMERICAN the one he made and said of it: "The performance of the Mak well repays all

the work put into it, the definition is much superior to that of a simple reflector."

Two other Maksutovs were also nearly finished. One could not be brought to full perfection and finally trailed off into a state of innocuous desuetude. The other, shown in the illustration on the opposite page, has been virtually completed by Dave Broadhead of Wellsville, N Y.

This is a Mak of the inventor's "simplest and most fundamental system," which is basically photographic but has a support for a Newtonian diagonal for visual use. The latter can be substituted for the film holder merely by reaching through the hand hole in the side of the tube and replacing it with the film-holder support shown in the insert sketch. These two supports may be exchanged by means of a wing nut that attaches them to the center of the corrector lens; there is no spider.

"Visually," Broadhead says, "the Mak gives a wonderful view and all that the eye can take; the exit pupil is a little larger than the pupil of the eye. The stars are sharp to the very edges of the field, a fact that psychologically increases the apparent field diameter."

Circumstances forced Broadhead temporarily to set this telescope aside before it could be completed by the addition of a drive, but it is far from a dead duck. Meantime it is hoped that a description of it will reactivate those whose Mak meniscus corrector lens blanks are still unfinished, perhaps because they are waiting to see how other Maks make out. Or perhaps they will agree to transfer these blanks to other owners who will convert them into the vital parts of Maksutovs. Such aspirants cannot now obtain blanks from the original source of supply; there is no mold.

The drawing contains most of the description of the Broadhead Maksutov. The cored aluminum fork, cast thin from a furnace in Broadhead's cellar shop (which is also equipped with lathe, shaper and the fundamental machine tools), is a splendid featherweight example of skilled workmanship

In his article in the October, 1944, Scientific American, Schell pointed out the chief advantage to the builder of the Maksutov over the otherwise similar Schmidt: the Schmidt corrector plate has a shallow and irregular curve that is difficult to make, while the meniscus corrector lens of the Mak has two spherical curves that are much less difficult. Like the Schmidt, the Mak enjoys the advantage of a closed tube, with its accompanying suppression of internal air currents that damage good seeing; and like the Schmidt the Mak system is aplanatic, having neither spherical aberration nor coma.

In the specifications worked out by Schell and followed by Broadhead and the others, the primary mirror at the bottom of the tube is made from a standard 8-inch Pyrex telescope blank to a radius of curvature of 65.856 inches. The corrector lens, .800-inch thick, has an internal radius of curvature of 12.688 inches, and an external radius 12.224 inches. Primary and lens are separated 43.128 inches. As these precise measurements suggest, the Mak is scarcely a job for a novice. Letters from those who have worked on Maks, largely discussing suitable tests—Ronchi and interference, mainly—are available on loan to new workers.

In July, 1946, C. J. Tenukest, R. Shaeler and H. Pinnock of New South Wales, Australia, described in *The Journal of the British Astronomical Association* a 6-inch Maksutov built from data in the Maksutov article in the *Journal of the Optical Society of America* and in Scientific American. For the corrector lens they used crown glass of index 1.51694 instead of 1.517, and also of a different thickness, and were thus forced to recalculate the specifications. Their Mak was a success. "Remarkably small and sharp images of stars were obtained," they stated, "free from coma and color. Such images are hardly possible with reflectors even on the most perfect night. The image of Jupiter was as sharp as if viewed through a first-grade refractor, yet the bluish halo visible around the disk with even the best glass was entirely absent. The image was crisp and colorless."

Slabs of glass at least 1⅜ inches thick and having characteristics close enough to that specified by Maksutov (5163641) may be available from American manufacturers, though not in the approximate meniscus form cast by Corning.

In his article Maksutov stated that he invented his telescope in August, 1941, and that it was patented in the U.S.S.R. on November 3, 1941. After the war, when Holland emerged from its wartime confinement, the Dutch optical designer A. Bouwers published in English his book *Achievements in Optics* (Elsevier Publishing Co., New York) which described a telescope essentially identical with the Maksutov. With the secret cooperation of the Dutch patent office, Bouwers had patented this type of telescope July 7, 1941, or four months before Maksutov. It is now said that K. Penning, a German, applied for a German patent on the same principle March 6, 1941.

N. J. Schell has suggested that the closed-tube advantages of refractors might be obtained for all reflectors by the addition of a plane-parallel plate of glass at their skyward end. This idea has been advocated many times previously. It resembles the famous Hindu rope trick—everyone knows about it and everyone believes in it, but no example of its actual application has yet been found. The plane-parallel plate could be coated to reduce losses in light transmission due to the surfaces.

AN INDEX OF ARTICLES AND AUTHORS

The following index lists all the articles and authors that appeared in SCIENTIFIC AMERICAN *during 1949. It also lists the principal book review in each issue. Shorter book notes are not indexed.*

BIBLIOGRAPHY

Readers interested in further reading on the subjects covered by articles in this issue may find the lists below helpful The lists are not intended as bibliographies of source material for the articles The references selected will provide supplementary information

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